TITLE OF THE INVENTION

Aerosol Deliver Apparatus IV

Applicant Number One: Sunil Dhuper, M.D.

Citizenship: US

Residence: 47, Red Ground Road, Old Westbury NY 11568

Applicant Number Two Sarita Dhuper, M.D.

Citizenship: US

Residence: 47, Red Ground Road, Old Westbury NY 11568

REFERENCE TO A SEQUENCE LISTING, A TABLE, OR A COMPUTER PROGRAM LISTING COMPACT DISK APPENDIX

Not Applicable

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable

CROSS-REFERENCE TO RELATED APPLICATIONS

3967619	Jul., 1976	Story et al.	
4484577	Nov., 1984	Sackner et al.	128/200
4534343	Aug., 1985	Nowacki et al.	128/203
4790305	Dec., 1988	Zoltain et al	128/203
4823784	Apr., 1989	Bordoni et al.	
4926852	May, 1990	Zoltain et al.	128/203
5020530	Jun., 1991	Miller et al.	
5027806	Jul., 1991	Zoltain et al.	128/203
5752502	May 1998	King et al.	128/200
4819629	Apr., 1989	Jonson	128/200
D272559	Feb., 1984	Guth	D24/110
D295321	Apr., 1988	Hollworth	D24/110
D342993	Jan., 1994	Fathi	D24/110
D373630	Sep., 1996	Berg et al.	D24/110
5139016	Aug., 1992	Waser	128/200
5178138	Jan., 1993	Walstrom et al.	128/200
5063921	Nov.,1991	Howe	128/200
D442685	May, 2001	Sladek	
5738087	Apr., 1998	Key	128/200
5497765	Mar., 1996	Proud, et al	128/200
5431154	Jul., 1995	Siegel et al.	128/200
5078131	Jan., 1970	Greenfield	128/200
5320094	Jun., 1994	Lombe et al.	128/200

5617844	Apr., 1997	King	128/200
3187748	Jun., 1995	Mitchell et al.	128/200
5848587	Dec., 1998	King	128/200
US Pat. App. #20020121275	Sept., 2002	Johnson	

BACKGROUND OF THE INVENTION

This invention relates to an improved aerosol inhalation device and particularly to an aerosol enhancement device which:

- can be used as a facemask to deliver precise fraction of inspired oxygen
- can be used as a 100% oxygen non-rebreather mask
- can deliver a single gas or a mixture of gases to yield varying gas densities that can enhance aerosol delivery
- can deliver an individual gas like nitrogen, oxygen, room air, helium, etc. or a single premixed gas or a mixture of individual gases to yield a final mixture which can deliver 100% oxygen or precise fraction of inspired oxygen or attain a mixture with a desired gas density and a desired concentration of oxygen that is physiologically compatible with life
- can deliver aerosol medication with a metered dose inhaler
- can deliver aerosol medication with standard small volume nebulizer
- can deliver aerosol medication with an MDI and/or a standard small volume nebulizer simultaneously
- can deliver aerosol medication with an MDI and/or a small volume nebulizer and simultaneously deliver a desired gas density to enhance aerosol delivery
- can deliver aerosol medication with an MDI and/or a small volume nebulizer; can deliver a desired gas density to enhance aerosol delivery; and deliver a desired fraction of inspired oxygen to a hypoxemic patient
- includes a reservoir in the form of a bag or an expandable/collapsible corrugated tubing for storage of aerosol generated by a nebulizer during exhalation.
- includes a valve system to prevent waste of medication generated by a nebulizer chamber during exhalation and to prevent rebreathing of exhaled carbon dioxide
- includes a valve system to prevent entrainment of room air during inhalation and for exit of carbon dioxide during exhalation
- can be used with a Continuous Positive Airway Pressure (CPAP) or a Bi-level Positive Airway Pressure (BIPAP) system
- can be introduced in a ventilatory circuit with the ability to deliver aerosol medication with a metered dose inhaler and/or a nebulizer

- includes a filter system to trap exhaled aerosol particles while allowing the exhaled gas (es) to escape into room air
- includes a filter system with a valve to prevent entrainment of room air during inhalation and to trap the exhaled aerosol particles while allowing exhaled gas (es) to escape into room air
- includes a collapsible/expandable spacer device that can be fully collapsed and made compact when not in use for delivery of aerosol medications and be partially or fully expandable when in use for aerosol medication delivery via an MDI or a nebulizer
- can serve as an ambu-bag for resuscitation
- can be used to deliver anesthetic gas (es)

MDI drug canisters are typically sold by manufacturers with a boot that includes a nozzle, an actuator, and a mouthpiece. Patients can self-administer the MDI medication using the boot alone but the majority of patients have difficulty in synchronizing the actuation of the MDI canister and inhalation of the medication. Spacers or valved chambers have been used with MDI boot to obviate the problem associated with patient coordination by helping to synchronize the actuation of MDI canister and patient inhalation and improve the delivery of medication by decreasing oropharyngeal deposition of aerosol drug. Many valved chambers of this type are commercially available. Examples of such spacers are- AeroChamber, U.S. Pat No. 4, 470,412 and 5,012,803; Optichamber, U.S. Pat No.5,385,140; Collapsible Chamber, U.S. Pat No 4,637,528 and 4,641,644; Disposable Chamber U.S. Pat No 4,953,545; or Collapsible and Disposable Chamber U.S. Pat Application No. 20020129814. These devices are expensive and may be alright for chronic conditions that require frequent use of MDI inhalers provided the cost and labor involved in frequent delivery of medication is acceptable to the patient. However, under acute symptoms, such devices may fail to serve the purpose and lead to an inadequate delivery of medication.

Aerosol delivery devices that use standard small volume nebulizers are commonly used in acute conditions as they are cheap and overcome the inhalation difficulties associated with actuation of MDI and synchronization of inhalation by the patient. Nebulizers are fraught with numerous problems as well. The medication dose used is about 10 times of that used with an MDI and hence the increased cost without any added proven clinical benefit.

Secondly, the majority of the nebulized medication is wasted during exhalation. Thirdly, the time taken to deliver the medication is several times that of an MDI and the labor cost of respiratory therapist may outweigh the benefits of nebulizers compared with MDIs. Breath actuated nebulizer (s) with reservoir have been designed to overcome the medication waste. Example of one such device is U.S. Pat No. 5,752,502. However, these devices are expensive and still have all the other problems associated with nebulizer use alone. Other examples of aerosol inhalation devices would be U.S. Pat. No 4,210,155, in which there is a fixed volume mist accumulation chamber for use in combination with a nebulizer and a TEE connection. Problems with prior art devices such as described are a significant waste of medication, a non-uniform concentration of delivered medication, expensive, and difficult to use. Many such devices are commercially available in which the nebulizer is directly attached to a TEE connector without any mixing chamber. All the afore mentioned devices can be used with either an MDI or a nebulizer but not both, and hence, face the difficultly associated with either system alone. Other devices have tried to overcome the above problems by incorporating a mixing chamber in the device with adaptability to be used with an MDI or standard nebulizer. U.S. Pat. Application No. 20020121275 is an example of one such device. However, the device is plagued with problems typical of such devices. Just like other prior art devices, this device as well fails to incorporate some of the key the features necessary for enhanced aerosol delivery. A list of problems associated with this device and other similar devices are outlined below:

(1) The entrained airflow in this device interferes with the MDI plume as well as the plume generated by a nebulizer resulting in increased impaction losses of aerosol generated by either an MDI or nebulizer.

(2) The device does not have the ability to deliver a desired precise fraction of inspired oxygen to a hypoxic patient and simultaneously deliver aerosol medication with either a metered dose inhaler or a nebulizer.

(3) The device cannot deliver a gas with a desired density to improve aerosol delivery and a desired fraction of inspired oxygen to a hypoxemic patient

(4) The device does not have the ability to deliver different density gases with a desired fraction of inspired oxygen simultaneously while retaining the ability to deliver aerosol medication at the same time with either an MDI or a nebulizer

(5) the device does not have the ability to deliver a mixture of multiple gases to a patient and simultaneously maintain a desired fraction of inspired oxygen

(6) the device does not serve as a facemask for delivering varying concentrations of inspired oxygen from room air to 100% but serves solely as an aerosol delivery device

(7) the device does not have a reservoir chamber-either as a bag or as a large volume tubing t store nebulized medication that is otherwise wasted during exhalation. The holding chamber of this device varies from 90cc to 140cc and is not enough to serve as a reservoir for the volume of nebulized medication generated during exhalation and hence in a normal sized adult most of the medication generated during exhalation is wasted

(8) there is no mechanism in the device to prevent entrainment of room air which forms the

bulk of volume during inhalation. The fraction of inspired oxygen and the density of gas mixture inhaled by the patient may vary with every breath with this device depending on the volume of entrained room air which may vary with each breath

(9) the device does not have any valve system to prevent exhaled carbon dioxide from entering the holding chamber. Rebreathing of carbon dioxide from the holding chamber on subsequent inhalation can be extremely detrimental to a patient and extremely dangerous under certain clinical conditions

(10) the device does not have the capability of delivering medication with an MDI and a nebulizer simultaneously

(11) the device has a fixed volume-holding chamber, which makes the device extremely large and cumbersome to deliver medication.

Our device overcomes all the difficulties and problems associated with this and all the prior art devices. Our device incorporates all the desired features to make it a compact, user friendly economical, and multipurpose aerosol device for both acute and chronic use with either an MDI or a nebulizer or with both MDI and nebulizer simultaneously as warranted by the patient's clinical circumstances. Our device also retains the ability to deliver a desired fraction of inspired oxygen and deliver a desired gas density to decrease the work of breathing and simultaneously deliver and enhance aerosol medication delivery.

SUMMARY OF THE INVENTION

The present invention provides an aerosol medication delivery apparatus, which incorporates the aforementioned advantages. The inventive device includes a fixed volume or a collapsible/expandable MDI holding chamber, a fixed volume or a collapsible/expandable nebulizer chamber, a system of connecting the two chambers with 2 or more hollow collapsible/expandable or fixed volume cylindrical connecting tubes. The MDI holding chamber maybe a fixed volume chamber or a collapsible/expandable chamber or a combination of the two i.e., partly fixed and partly collapsible/expandable chamber. The collapsible feature of the device makes it compact when solely in use for delivery of single gas or different gas mixtures while the expandable feature can be utilized when delivering aerosol medication with an MDI and/or a nebulizer.

The collapsible/expandable MDI chamber has a hollow cylindrical rigid inlet port at one end and a similar outlet port at the other end. When fully collapsed the outlet and the inlet port may be fused to each other to form a continuous hollow rigid cylindrical tube. When the holding chamber is fully expanded the outlet and inlet tubes stay disconnected. The holding chamber may be kept patent by internal support with a coiled metal or plastic wire. The rings of the coiled wire come together when the chamber is collapsed and stay separated when it is expanded. Alternatively, the MDI chamber may be constructed with a collapsible/expandable corrugated plastic tubing, which does not require any coiled metal or plastic wire support for maintaining patency of the chamber. The volume of the chamber may vary form 0.10 liters to 2.0 liters to accommodate both pediatric and adult patients. When partially or fully expanded, the chamber may also serve as a reservoir to prevent aerosol generated during exhalation from being wasted.

The central rigid inlet port is connected to a universal boot adapter panel with an opening to accommodate the boot of any commercially available MDI such that medication can be delivered to the MDI chamber on actuation of the MDI canister. For aerosol delivery with nebuliser, the universal boot adapter is disconnected from the inlet port, which now fuses with the outlet port of the nebulizer chamber. The inlet of the MDI chamber is connected to the outlet to the nebulizer chamber with two additional peripheral hollow cylindrical connecting tubes; the two tubes have two outlet ports at 3 and 9 o'clock positions in the nebulizer chamber and two inlet ports in similar locations in the MDI chamber. The

distance between the connecting tubes and the length of the connecting tubes allows for any commercially available MDI boot to be accommodated easily between the MDI and the nebulizer chambers. At the inlet end of the MDI chamber, the peripheral hollow cylindrical connecting tubes split into multiple micrometric openings that are distributed at intervals along the entire circumference of the MDI chamber's inlet. This allows the flow of gas(es) from the two openings in the nebulizer chambers outlet to the multiple openings distributed all along the circumference of the MDI chamber's inlet. The pattern of flow of the gas(es) through multiple openings that are distributed along the circumference of the MDI chamber's inlet is such that it does not interfere with the plume of the MDI when it is actuated. Also this arrangement allows different desired density gas(es) with a desired fraction of inspired oxygen to flow into the MDI chamber to enhance aerosol delivery from MDI and to deliver oxygen to a patient if necessary. The flow pattern of the gas(es) in addition minimizes the impaction losses of aerosol generated by an MDI.

The outlet rigid tube of the MDI chamber has an inhalation flap valve and a flap seat. The flap valve moves away from the flap valve seat on inhalation to allow the flow of medication from the MDI chamber to the patient. On exhalation the flap valve presses against the flap valve seat which prevents carbon dioxide exhaled during exhalation from entering into the MDI chamber. The outlet tube has an exhalation flap valve assembly with an exhalation flap valve and a valve seat on the superior or inferior surface. The flap valve moves away from the flap valve seat on exhalation to allow the exhaled gases to exit the outlet tube and presses against the valve seat on inhalation to prevent any entrainment of any room air gases on inhalation. The provision of a filter at this opening may be optional depending on the conditions under which aerosol is being delivered. The filter can trap all exhaled aerosol particles while allowing the gases to exit from this port. A flap valve may again be provided at the end of the filter to prevent entrainment of room air gas during inhalation and to allow exit of all exhaled gas(es).

The nebulizer chamber has an inlet port with a central cylindrical hollow rigid tube for entry of one or more gases into the nebulizer chamber; an outlet port, a port for a nebulizer, and a port for a reservoir (a bag reservoir or a collapsible/expandable corrugated plastic tubing reservoir), the reservoir bag has one or more inlet ports for inflow of desired gases. There are two additional openings at 3 and 9 o'clock positions for connection of peripheral

tubes that connect the MDI chamber and the nebulizer chamber. The outlet of the nebulizer chamber has a rigid hollow cylindrical tube similar to that seen in the MDI chamber's inlet. The port of the nebulizer chamber remains plugged with a cap when MDI is in use. The cap is unplugged and the outlet port of the nebulizer fuses with the inlet port of the MDI chamber when nebulizer is to be used. When aerosol delivery is desired with a nebulizer, the nebulizer is connected to the nebulizer port, the nebulized medication flows through the peripheral connecting tubes between the MDI chamber and the nebulizer chamber through multiple openings distributed along the circumference of the MDI chamber's inlet. The universal boot adapter assembly may be disconnected from the central rigid tube of MDI the chamber, which could now be plugged with a cap. Alternatively, the central inlet tube of the MDI chamber and the central outlet tube of the nebulizer chamber can both uncapped and the two tubes fused to each other by moving the MDI chamber closer to the nebulizer chamber by collapsing the peripheral connecting tubes. The aerosol generated by the nebulizer can now flow from the nebulizer chamber to the MDI chamber via the central connection between the MDI chamber and the nebulizer chamber, as well as via the peripheral connections between the two chambers via the peripheral connecting tubes at 3 and 9 o'clock positions. The connecting tubes between the MDI and nebulizer chambers are made collapsible/expandable in a manner identical to the principles of the expandable/collapsible MDI chamber itself. This will allow the MDI and the nebulizer chambers to be moved closer to each other to be fused during nebulizer operation or to be disconnected and moved apart to accommodate MDI in the space between the MDI and the nebulizer chambers during MDI operation.

The aerosol reservoir may comprise of a collapsible/expandable bag made of plastic or neoprene, a fixed chamber, or a collapsible/expandable corrugated plastic tubing. The volume of the reservoir could vary from 0.1 liter to 2.0 liters to meet the needs of both pediatric and adult patients. The reservoir could be attached to a reservoir port in the nebulizer chamber or alternatively it could be attached to the inlet port of the nebulizer chamber to store the aerosol generated during exhalation which would otherwise, have been wasted as is the case with most TEE nebulizers. During the subsequent inhalation the aerosol stored in the reservoir bag during exhalation would flow from the nebulizer chamber into the

MDI chamber via central and/or peripheral connections and then through the mouthpiece or facemask to the patient.

Additional inlet ports may be available directly on the nebulizer chamber or on the reservoir bag or on the corrugated plastic tubing reservoir which will allow one of more, unmixed or premixed gases to flow into the nebulizer chamber and/or the reservoir at different flow rates to achieve a desired density, viscosity, humidity and fraction of inspired oxygen to simultaneously enhance medication delivery and deliver oxygen to a hypoxemic patient. The gases used may be oxygen, nitrogen, helium, heliox (premixed), room air, various anesthesia gases, various diagnostic gases, i.e.xenon, krypton etc. When not in use for aerosol delivery either via MDI or nebulizer the device could be used solely to deliver desired oxygen concentration or other aforementioned gases via a facemask which can be connected to outlet of the MDI chamber. The equipment in this case will be made extremely compact by fully collapsing the MDI chamber, fully collapsing the peripheral connecting tubes, and fully collapsing the corrugated plastic reservoir tubing connected to the nebulizer chamber. The nebulizer outlet port in the nebulizer chamber may be plugged with a cap when only delivering a gas without aerosolized medication or the inlet port of MDI chamber and the outlet port of the nebulizer chamber may be fused. The desired gas(es) can now flow to the patient from the reservoir bag/tubing to the MDI chamber via the central and/or peripheral connections between the two chambers and to the patient via a facemask.

The device can also be incorporated into the inspiratory limb of the ventilatory circuit by making connections at two sites- between the inspiratory tubing and the outlet port of the MDI chamber at one end and between the inlet port of the nebulizer chamber and the inspiratory tubing at the other end. The device can now deliver aerosol medication with MDI or nebulizer to the patient on mechanical ventilation. This arrangement will have the distinct advantage of delivering the precise dose via MDI (ex-actuator) as specified by the manufacturer. This arrangement allows the MDI canister to be actuated using the MDI boot and actuator as specified by the manufacturers as opposed to commercially available custom designed universal actuators that are currently available to fit nozzles of various MDIs. Hence, this mode of delivery is different from all the prior art devices which have used custom designed universal actuators in ventilatory circuit to deliver aerosol by MDI as those devices fail to meet the ex-actuator delivery of dose as specified by the manufacturer. Hence,

the ex-actuator dose output for each MDI will be different from that specified by the manufacturer. Our device obviates that problem.

Alternatively, our device, like numerous prior art devices, can incorporate a custom designed universal actuator on the inlet port of the MDI chamber to accommodate the nozzles of all commercially available MDI canisters to deliver aerosol via MDI, as opposed to a universal MDI boot assembly to accommodate the boot of all commercially available MDIs. In this case all other features of the device would remain the same except that the MDI chamber and the nebulizer chamber may be fused at the center without any connecting tubes at the 3 and 9 o'clock positions. Alternatively, the nebulizer and MDI chambers maybe connected only at peripheral 3 and 9 o'clock positions with collapsible connecting tubes or fixed rigid tubes without intervening space between the MDI and the nebulizer chambers for MDI boot assembly which will no longer be required. Alternatively, nebulizer and MDI chambers maybe connected or fused at both central and peripheral locations.

Alternatively, the collapsible/expandable MDI chamber and the collapsible/expandable MDI chamber may be fused to form a single chamber and the MDI boot assembly instead of now being fitted at the inlet of the MDI chamber fits at the inlet of the nebulizer chamber where an MDI boot can be attached to deliver aerosol medication via MDI. The boot assembly may also be designed to accommodate a nebulizer Tee piece which may generate aerosol particles via a nebulizer to deliver it into the collapsible / expandable MDI and nebulizer chambers. The Tee piece in this case will have one end of the horizontal limb completely closed so that no aerosol particles will escape out of the holding chamber during exhalation phase and there may be no need for a reservoir bag as the collapsible/expandable tubing of the MDI and nebulizer chambers when expanded will create a volume that will serve as a reservoir for storage of aerosol medication generated during the exhalation phase. Alternatively, the Tee piece may be open at both ends, one open end of which may be connected to the inlet of the nebulizer chamber and the other free end of which may be connected to a second Tee piece. The vertical limb of the second Tee piece may now serve as the inlet for the reservoir bag or the corrugated reservoir tubing and one end of the horizontal limb of the second Tee piece remaining closed.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

Further features of the present invention will become apparent in the accompanied drawings as well as the detailed description of the preferred embodiments.

Fig 1A and Fig 1B are plan views of the longitudinal length of aerosol delivery apparatus IV according to one embodiment of the present invention, incorporating the features described in the summary of the invention.

Fig 1C and Fig 1D are plan views of the longitudinal length of aerosol delivery apparatus IV according to the first alternative embodiment of the present invention.

Fig 1E and Fig 1F are plan views of the longitudinal length of aerosol delivery apparatus IV according to the second alternative embodiment of the present invention.

Fig 2A and Fig 2B are plan views of the longitudinal length of aerosol delivery apparatus IV according to the third alternative embodiment of the present invention.

Fig 2C and Fig 2D are plan views of the longitudinal length of aerosol delivery apparatus IV according to the fourth alternative embodiment of the present invention.

Fig 2E and Fig 2F are plan views of the longitudinal length of aerosol delivery apparatus IV according to the fifth alternative embodiment of the present invention.

Fig 3A and Fig 3B are expanded plan views of MDI chamber 1a according to the present invention as described in Fig 1A.

Fig 3C is an expanded plan view of MDI chamber 1a according the first alternative embodiment of the present invention as described in Fig 3A and Fig 3B.

Fig 3D and Fig 3E are expanded plan views of MDI chamber 1a according to the second alternative embodiment of the present invention as described in Fig 3A and 3B.

Fig 3F is an expanded plan view of MDI chamber 1a according to the third alternative embodiment of the present invention as described in Fig 3A and 3B.

Fig 3G and Fig 3H are expanded plan views of MDI chamber 1a according to the fourth alternative embodiment of the present invention as described in Fig 3A and 3B.

Fig 3I is an expanded plan view of MDI chamber 1a according to the fifth alternative embodiment of the present invention as described in Fig 3A and 3B.

Fig 4A and 4B are expanded plan views of tubes 50a or 51a according to the present invention as described in Fig 1A.

Fig 4C and 4D are expanded plan views of tubes 50a or 51a according to the first alternative embodiment of the present invention as described in Fig 4A and 4B.

Fig 4E and 4F are expanded plan views of tubes 50a or 51a according to the second alternative embodiment of the present invention as described in Fig 4A and 4B.

Fig 5A is an expanded cross-sectional view of the inlet end 2a of the invention as described in Fig 1A.

Fig 5B is an expanded cross-sectional view of the inlet end 2a according to the first alternative embodiment of the present invention as described in Fig 5A.

Fig 6A is an expanded cross-sectional view of the inhalation/exhalation valve assemblies 32a or 35a of the invention as described in Fig 1A.

Fig 6B is an expanded cross-sectional view of the inhalation/exhalation valve assemblies 32a or 35a of the first alternative embodiment of the present invention as described in Fig 6A.

Fig 6C is an expanded cross-sectional view of the inhalation/exhalation valve assemblies 32a or 35a of the second alternative embodiment of the present invention as described in Fig 6A.

Fig 7A is a plan view of the longitudinal length of the mouthpiece according to one embodiment of the present invention.

Fig 7B is a plan view of the longitudinal length of the facemask according to one embodiment of the present invention.

Fig 8A is an expanded plan view of the longitudinal length of aerosol delivery apparatus IV according to alternative embodiment of the present invention as described in Fig 1E.

Fig 8B is an expanded plan view of the longitudinal length of aerosol delivery apparatus IV according to the first alternative embodiment of the present invention as described in Fig 8A.

Fig 8C is an expanded plan view of the longitudinal length of aerosol delivery apparatus IV according to the second alternative embodiment of the present invention as described in Fig 8A.

Fig 8D is an expanded plan view of the longitudinal length of aerosol delivery apparatus IV according to the alternative embodiment of the present invention as described in Fig 2E.

Fig 8E is an expanded plan view of the longitudinal length of aerosol delivery apparatus IV according to the first alternative embodiment of the present invention as described in Fig 8D.

Fig 8F is an expanded plan view of the longitudinal length of aerosol delivery apparatus IV according to the second alternative embodiment of the present invention as described in Fig 8D.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will now be described in detail by reference to the drawing figures, where as like parts as indicated by like reference numerals.

Fig 1A is a plan view of the longitudinal length of aerosol delivery apparatus IV according to one embodiment of the present invention, incorporating the features described in the summary of the invention. Figure 1A is a plan view of the invention that may be used with a metered dose inhaler (MDI) or a nebulizer. The illustration here describes the use of this device preferentially with an MDI. The device has two hollow chambers, a metered dose inhaler chamber 1a, and a nebulizer chamber 4a. The MDI chamber 1a has an inlet end 2a and an outlet end 3a.The nebulizer chamber 4a similarly has an inlet end 5a and an outlet end 6a. The inlet end 2a has three hollow cylindrical inlet tubes, a central tube 7a and two peripheral tubes 10a and 13a located at three o'clock to nine o'clock positions, respectively. The central hollow cylindrical tube 7a has an inlet end 8a and an outlet end 9a .The peripheral tube 10a has an inlet end 11a and an outlet end 12a and the peripheral tube 13a similarly has an inlet end 14a and an outlet ed 15a. The outlet end 3a of the MDI chamber 1a has a hollow cylindrical tube 16a with an inlet end 17a and an outlet end 18a. The MDI chamber 1a may be made of plastic, paper, or metal. The chamber 1a may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 19a and grooves 20a. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 21a of the coil are demonstrated in the figure as dotted lines. The distance 22a and 23a between the two adjacent ridges, rings of the coil, or grooves may be equal. Alternatively, the chamber may be made of stiff corrugated plastic that may not require any additional support to maintain

patency of the chamber. **The figure demonstrates the expanded illustration of the MDI camber 1a .**

The inlet end 8a of the central tube 7a is attached to the outlet end 27a of the boot 25a of a metered dose inhaler 24a. The inhaler 24a has a boot 25a with an inlet end 26a and an outlet end 27a.A canister 28a is introduced into the boot 25a through the inlet end 26a and the nozzle 29a of the MDI 24a is attached to an actuator 30a. The actuator 30a has an opening or an aperture 31a. On actuation of the MDI canister 28a, the medication aerosol particles are generated through the opening 31a of the actuator 30a, and enter into the chamber 1a through the outlet end 9a of the central tube 7a.

The outlet tube 16a of the MDI chamber 1a has two valve assemblies disposed between the inlet end 17a and the outlet end 18a –the inhalation valve assembly and an exhalation valve assembly .The inhalation flap valve assembly has a circular flap valve seat 32a that has a circular opening 33a and a flap valve 34a as demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 35a that has a circular opening 36a and a flap valve 37a as demonstrated by the dotted line. On inhalation, the inhalation flap valve 34a moves away from the valve seat 32a for the aerosol particles to move from the MDI chamber 1a to the patient through the opening 33a in the valve seat 32a of the tube 16a. On exhalation, the flap valve 34a moves towards the flap valve seat 32a and closes the opening 33a to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 1a thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 32a prevents any protrusion of the flap valve 34a through the opening 33a: The exhalation flap valve assembly has a flap valve 37a that presses against the flap valve seat 35a on inhalation and completely occludes the opening 36a to prevent any room air entrainment i.e. not

allowing the air from the atmosphere to enter into the tube 16a on inhalation. On exhalation the flap valve 37a moves away from the flap valve seat 35a for the air exhaled by the patient to escape into the atmosphere from tube 16a through the opening 36a.

The nebulizer chamber 4a has a hollow cylindrical inlet tube 38a with an inlet end 39a and an outlet end 40a.The inlet and 39a can be attached to a single or multiple gas sources to obtain a mixture of gases with a desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient. The nebulizer chamber 4a has a hollow cylindrical outlet tube 41a that has an inlet end 42a and an outlet end 43a.The outlet end 43a may remain plugged with a cap when the device is in use with a metered dose inhaler. The nebulizer chamber also has two hollow cylindrical tubes, 44a and 47a, at three o'clock and nine o'clock positions. Tube 44a has an inlet end 45a and an outlet end 46a, whereas the tube 47a has an inlet end 48a and an outlet end 49a. The inlet end 11a of the tube 10a the inlet end 5a of the MDI chamber 1a is connected to the outlet end 46a of the tube 44a at the outlet end 6a of the nebulizer chamber 4a with a collapsible/expandable stiff corrugated plastic tubing 50a and similarly the inlet end 14a of tube 13a is connected to the outlet end 49a of tube 47a with a collapsible/expandable corrugated plastic tubing 51a. The collapsible/expandable tubings 50a and 51a are demonstrated to be fully expanded in figure 1A to accommodate MDI boot 25a between the MDI chamber 1a and the nebulizer chamber 4a.

The nebulizer chamber has an inlet port 52a for connection with a standard small volume nebulizer 53a. Chamber 4a also has another inlet 54a for connection to a reservoir bag 55a. The reservoir bag 55a serves to store the aerosol particles generated by the nebulizer 53a during the exhalation phase to be inhaled on the next breath thus improving aerosol

medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The bag 55a has two small inlets 56a and 57a to be connected to one or more gas sources to obtain a mixture of gases with a desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

Fig 1B is a plan view of the longitudinal length of aerosol delivery apparatus IV according to one embodiment of the present invention, incorporating the features described in the summary of the invention. Figure 1B is a plan view of the invention just like the one described in figure 1A that may be used with a metered dose inhaler (MDI) or a nebulizer. The illustration here is describes the use of this device preferentially with an MDI. The device has two hollow chambers, a metered dose inhaler chamber 1b, and a nebulizer chamber 4b. The MDI chamber 1b has an inlet end 2b and an outlet end 3b.The nebulizer chamber 4b similarly has an inlet end 5b and an outlet end 6b. The inlet end 2b has three hollow cylindrical inlet tubes, a central tube 7b and two peripheral tubes 10b and 13b located at three o'clock to nine o'clock positions. The central hollow cylindrical tube 7b has an inlet end 8b and an outlet end 9b .The peripheral tube 10b has an inlet end 11b and an outlet end 12b and the peripheral tube 13b similarly has an inlet end 14b and an outlet ed 15b. The outlet end 3b of the MDI chamber 1b has a hollow cylindrical tube 16b with an inlet end 17b and an outlet end 18b. The MDI chamber 1b may be made of plastic, paper, or metal just as described in figure 1A. Chamber 1b is a collapsible/expandable cylindrical chamber with multiple ridges 19b and grooves 20b.The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 21b of the coil

are demonstrated in the figure as dotted lines. **The MDI chamber 1b in this figure is demonstrated to be fully or partially collapsed**. The distance 22b and 23b between the two adjacent ridges, rings of the coil , or grooves is reduced by pulling the rings of the coil, ridges or grooves together. When fully collapsed, the inlet end 17b of the tube 16b may be fused to the outlet end 9b of the tube 7b.

The inlet end 8b of the tube 7b is attached to the outlet end 27b of the boot 25b of a metered dose inhaler 24b. The inhaler 24b has a boot 25b with an inlet end 26b and an outlet end 27b.A canister 28b is introduced into the boot 25b through the inlet end 26b and the nozzle 29b of the MDI 24b is attached to an actuator 30b. The actuator 30b has an opening or an aperture 31b. On actuation of the MDI canister 28b, the medication aerosol particles are generated through the opening 31b of the actuator 30b, and enter into the chamber 1b through the outlet end 9b of the tube 7b.

The outlet tube 16b of the MDI chamber 1b has two valve assemblies disposed between the inlet end 17b and the outlet end 18b –the inhalation valve assembly and an exhalation valve assembly .The inhalation flap valve assembly has a circular flap valve seat 32b that has a circular opening 33b and a flap valve 34b as demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 35b that has a circular opening 36b and a flap valve 37b as demonstrated by the dotted line. On inhalation, the inhalation flap valve 34a moves away from the valve seat 32b for the aerosol particles to move from the MDI chamber 1b to the patient through the opening 33b in the valve seat 32b of the tube 16b. On exhalation, the flap valve 34b moves towards the flap valve seat 32b and closes the opening 33b to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 1a thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 32b prevents any protrusion of the flap valve 34b through the opening 33b. The exhalation flap

valve assembly has a flap valve 37b that presses against the flap valve seat 35b on inhalation and completely occludes the opening 36b to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the tube 16b on inhalation. On exhalation the flap valve 37b moves away from the flap valve seat 35b for the air exhaled by the patient to escape into the atmosphere from tube 16b through the opening 36b.

The nebulizer chamber 4b has a hollow cylindrical inlet tube 38b with an inlet end 39b and an outlet end 40b.The inlet and 39b can be attached to a single or multiple gas sources to obtain a mixture of gases with a desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient. The nebulizer chamber 4b has a hollow cylindrical outlet tube 41b that has an inlet end 42b and an outlet end 43b.The outlet end 43b may remain plugged with a cap when the device is in use with a metered dose inhaler. The nebulizer chamber also has two hollow cylindrical tubes, 44b and 47b, at three o'clock and nine o'clock positions. Tube 44b has an inlet end 45b and an outlet end 46b, whereas the tube 47b has an inlet end 48b and an outlet end 49b. The inlet end 11b of the tube 10b is connected to the outlet end 46b of the tube 44b with a collapsible/expandable stiff corrugated plastic tubing 50b and similarly the inlet end 14b of tube 13b is connected to the outlet end 49b of tube 47b with a collapsible/expandable corrugated plastic tubing 51b. The collapsible/expandable tubings 50b and 51b are demonstrated to be fully expanded in figure 1B to accommodate MDI boot 25b between the MDI chamber 1b and the nebulizer chamber 4b.

The nebulizer chamber has an inlet port 52b for connection with a standard small volume nebulizer 53b. Chamber 4b also has another inlet 54b for connection to a reservoir bag 55b. The reservoir bag 55b serves to store the aerosol particles generated by the nebulizer 53b during the exhalation phase to be inhaled on the next breath thus improving aerosol

medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The bag 55b has two small inlets 56b and 57b to be connected to one or more gas sources to obtain a mixture of gases with a desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

Fig 1C is a plan view of the longitudinal length of aerosol delivery apparatus IV according to the first alternative embodiment of the present invention. Figure 1C is a plan view of the invention that may be used with a metered dose inhaler (MDI) or a nebulizer. The illustration here is describes the use of this device preferentially with a nebulizer. The device has two hollow chambers, a metered dose inhaler chamber 1c, and a nebulizer chamber 4c. The MDI chamber 1a has an inlet end 2c and an outlet end 3c.The nebulizer chamber 4c similarly has an inlet end 5c and an outlet end 6c. The inlet end 2c has three hollow cylindrical inlet tubes, a central tube 7c and two peripheral tubes 10c and 13c located at three o'clock to nine o'clock positions. The central hollow cylindrical tube 7c has an inlet end 8c and an outlet end 9c .The peripheral tube 10c has an inlet end 11c and an outlet end 12c and the peripheral tube 13c similarly has an inlet end 14c and an outlet ed 15c. The outlet end 3c of the MDI chamber 1c has a hollow cylindrical tube 16c with an inlet end 17c and an outlet end 18c. The MDI chamber 1c may be made of plastic, paper, or metal. The chamber 1c may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 19c and grooves 20c.The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 21c of the coil are demonstrated in the figure as dotted lines. The distance 22c and 23c between the two adjacent ridges, rings of the coil, or grooves

may be equal.**The MDI chamber 1c in this figure is illustrated as fully expanded.** The inlet end 8c of the tube 7c is not attached to the MDI 24c as demonstrated in figure 1A. The MDI 24c is demonstrated separately in this figure .The inhaler 24c has a boot 25c with an inlet end 26c and an outlet end 27c.A canister 28c is introduced into the boot 25c through the inlet end 26c and the nozzle 29c of the MDI 24c is attached to an actuator 30c. The actuator 30c has an opening or an aperture 31c. On actuation of the MDI canister 28c, the medication aerosol particles are generated through the opening 31c of the actuator 30c.

The outlet tube 16c of the MDI chamber 1c has two valve assemblies disposed between the inlet end 17c and the outlet end 18c –the inhalation valve assembly and an exhalation valve assembly. The inhalation flap valve assembly has a circular flap valve seat 32c that has a circular opening 33c and a flap valve 34c as demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 35c that has a circular opening 36c and a flap valve 37c as demonstrated by the dotted line. On inhalation, the inhalation flap valve 34c moves away from the valve seat 32c for the aerosol particles to move from the MDI chamber 1c to the patient through the opening 33c in the valve seat 32c of the tube 16c. On exhalation, the flap valve 34c moves towards the flap valve seat 32c and closes the opening 33c to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 1c thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 32c prevents any protrusion of the flap valve 34c through the opening 33c. The exhalation flap valve assembly has a flap valve 37c that presses against the flap valve seat 35c on inhalation and completely occludes the opening 36c to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the tube 16c on inhalation. On exhalation the flap valve 37c moves away from the flap valve seat 35c for the air exhaled by the patient to escape into the atmosphere from tube 16c through the opening 36c.

The nebulizer chamber 4c has a hollow cylindrical inlet tube 38c with an inlet end 39c and an outlet end 40c.The inlet and 39c can be attached to a single or multiple gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient. The nebulizer chamber 4c has a hollow cylindrical outlet tube 41c that has an inlet end 42c and an outlet end 43c. The nebulizer chamber also has two hollow cylindrical tubes, 44c and 47c, at three o'clock and nine o'clock positions. Tube 44c has an inlet end 45c and an outlet end 46c, whereas the tube 47a has an inlet end 48c and an outlet end 49c. The inlet end 11c of the tube 10c is connected to the outlet end 46c of the tube 4c with a collapsible/expandable stiff corrugated plastic tubing 50c and similarly the inlet end 14c of tube 13c is connected to the outlet end 49c of tube 47c with a collapsible/expandable corrugated plastic tubing 51c. Quite unlike figure 1A the collapsible/expandable tubings 50c and 51c are now demonstrated to be collapsed but still fully patent. The inlet end 9c of the tube 7c is now fused to the outlet end 43c of the tube 41c .The inlet ends 11c and 14c may be fused to the outlet ends 46c and 49c respectively or may stay separated.

The nebulizer chamber has an inlet port 52c for connection with a standard small volume nebulizer 53c. The aerosol medication generated with the nebulizer 53c can enter the MDI chamber via a central connection between the tubes 7c and 41c or through the peripheral connections between the tubes 10c and 44c, and 13c and 47c. Chamber 4c also has another inlet 54c for connection to a reservoir bag 55c. The reservoir bag 55c serves to store the aerosol particles generated by the nebulizer 53c during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The bag 55c has two small inlets 56c and 57c to be

connected to one or more gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient. The MDI 24c can be connected to the inlet 40c and on actuation the aerosol particles generated by the MDI will be transferred from the nebulizer chamber 4c to the MDI chamber 1c via the central and two peripheral connections between the two chambers as described before.

Fig 1D is a plan view of the longitudinal length of aerosol delivery apparatus IV according to the first alternative embodiment of the present invention. Figure 1D is a perspective view of the invention that may be used with a metered dose inhaler (MDI) or a nebulizer. The illustration here is describes the use of this device preferentially with a nebulizer. The device has two hollow chambers, a metered dose inhaler chamber 1d, and a nebulizer chamber 4d. The MDI chamber 1d has an inlet end 2d and an outlet end 3d.The nebulizer chamber 4d similarly has an inlet end 5d and an outlet end 6d. The inlet end 2d has three hollow cylindrical inlet tubes, a central tube 7d and two peripheral tubes 10d and 13d located at three o'clock to nine o'clock positions. The central hollow cylindrical tube 7d has an inlet end 8d and an outlet end 9d .The peripheral tube 10d has an inlet end 11d and an outlet end 12d and the peripheral tube 13d similarly has an inlet end 14d and an outlet 15d. The outlet end 3d of the MDI chamber 1d has a hollow cylindrical tube 16d with an inlet end 17d and an outlet end 18d. The MDI chamber 1a may be made of plastic, paper, or metal. The chamber 1a may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 19d and grooves 20d. The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 21d of the coil are demonstrated in the figure as dotted

lines. **The chamber 1d in this figure is demonstrated to be fully or partially collapsed** The distance 22d and 23d between the two adjacent ridges, rings of the coil, or grooves is reduced by pulling the rings of the coil, ridges or grooves together. When fully collapsed, the inlet end 17d of the tube 16d may be fused to the outlet end 9d of the tube 7d. The distance 22d and 23d between the two adjacent ridges, rings of the coil, or grooves may be equal. The inlet end 8d of the tube 7d is not attached to the MDI 24d as demonstrated in figure 1A. The MDI 24d is demonstrated separately in this figure .The inhaler 24d has a boot 25d with an inlet end 26d and an outlet end 27d. A canister 28d is introduced into the boot 25d through the inlet end 26d and the nozzle 29d of the MDI 24d is attached to an actuator 30d. The actuator 30d has an opening or an aperture 31d. On actuation of the MDI canister 28d, the medication aerosol particles are generated through the opening 31d of the actuator 30d.

The outlet tube 16d of the MDI chamber 1d has two valve assemblies disposed between the inlet end 17d and the outlet end 18d –the inhalation valve assembly and an exhalation valve assembly. The inhalation flap valve assembly has a circular flap valve seat 32d that has a circular opening 33d and a flap valve 34d as demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 35d that has a circular opening 36d and a flap valve 37d as demonstrated by the dotted line. On inhalation, the inhalation flap valve 34d moves away from the valve seat 32d for the aerosol particles to move from the MDI chamber 1d to the patient through the opening 33d in the valve seat 32d of the tube 16d. On exhalation, the flap valve 34d moves towards the flap valve seat 32d and closes the opening 33d to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 1d thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 32d prevents any protrusion of the flap valve 34d through the opening 33d. The exhalation flap valve assembly has a flap valve 37d that presses against the flap valve seat 35d on inhalation

and completely occludes the opening 36d to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the tube 16d on inhalation. On exhalation the flap valve 37d moves away from the flap valve seat 35d for the air exhaled by the patient to escape into the atmosphere from tube 16d through the opening 36d.

The nebulizer chamber 4d has a hollow cylindrical inlet tube 38d with an inlet end 39d and an outlet end 40d. The inlet and 39d can be attached to a single or multiple gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient. The nebulizer chamber 4d has a hollow cylindrical outlet tube 41d that has an inlet end 42d and an outlet end 43d. The nebulizer chamber also has two hollow cylindrical tubes, 44d and 47d, at three o'clock and nine o'clock positions. Tube 44d has an inlet end 45d and an outlet end 46d, whereas the tube 47d has an inlet end 48d and an outlet end 49d. The inlet end 11d of the tube 10d is connected to the outlet end 46d of the tube 44d with a collapsible/expandable stiff corrugated plastic tubing 50d and similarly the inlet end 14d of tube 13d is connected to the outlet end 49d of tube 47d with a collapsible/expandable corrugated plastic tubing 51d. Quite unlike figure 1A the collapsible/expandable tubings 50d and 51d are now demonstrated to be collapsed but still fully patent. The inlet end 9d of the tube 7d is now fused to the outlet end 43d of the tube 41d. The inlet ends 11d and 14d may be fused to the outlet ends 46d and 49d respectively or may stay separated.

The nebulizer chamber has an inlet port 52d for connection with a standard small volume nebulizer 53d. The aerosol medication generated with the nebulizer 53d can enter the MDI chamber via a central connection between the tubes 7d and 41d or through the peripheral connections between the tubes 10d and 44d, and 13d and 47d.Chamber 4d also has another

inlet 54d for connection to a reservoir bag 55d. The reservoir bag 55d serves to store the aerosol particles generated by the nebulizer 53d during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The bag 55d has two small inlets 56d and 57d to be connected to one or more gas sources to obtain a mixture of gases with a desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

Fig 1E is a plan view of the longitudinal length of aerosol delivery apparatus IV according to the second alternative embodiment of the present invention. Figure 1E is a perspective view of the invention that may be used with both a metered dose inhaler (MDI) or a nebulizer. The MDI chamber 1e has an outlet end 3e.The nebulizer chamber 4e has an inlet end 5e .The inlet end of the MDI chamber 1e and the outlet end of the nebulizer chamber 4e are fused together, the point of fusion is labeled as 2e6e. The outlet end 3e of the MDI chamber 1e has a hollow cylindrical tube 16e with an inlet end 17e and an outlet end 18e. The MDI chamber 1e may be made of plastic, paper, or metal. The chamber 1e may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 19e and grooves 20e.The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 21e of the coil are demonstrated in the figure as dotted lines. The distance 22e and 23e between the two adjacent ridges, rings of the coil, or grooves may be equal. **The MDI chamber 1e in this figure is illustrated as fully expanded.**

The outlet tube 16e of the MDI chamber 1e has two valve assemblies disposed between the inlet end 17e and the outlet end 18e –the inhalation valve assembly and an

exhalation valve assembly .The inhalation flap valve assembly has a circular flap valve seat 32e that has a circular opening 33e and a flap valve 34e as demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 35e that has a circular opening 36e and a flap valve 37e as demonstrated by the dotted line. On inhalation, the inhalation flap valve 34e moves away from the valve seat 32e for the aerosol particles to move from the MDI chamber 1e to the patient through the opening 33e in the valve seat 32e of the tube 16e. On exhalation, the flap valve 34e moves towards the flap valve seat 32e and closes the opening 33e to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 1e thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 32e prevents any protrusion of the flap valve 34e through the opening 33e. The exhalation flap valve assembly has a flap valve 37e that presses against the flap valve seat 35e on inhalation and completely occludes the opening 36e to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the tube 16e on inhalation. On exhalation the flap valve 37e moves away from the flap valve seat 35e for the air exhaled by the patient to escape into the atmosphere from tube 16e through the opening 36e.

The nebulizer chamber 4e has a hollow cylindrical inlet tube 38e with an inlet end 39e and an outlet end 40e.The inlet and 39e can be attached to a single or multiple gas sources to obtain a mixture of gases with a desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles and /or to deliver a fixed concentration of oxygen to a hypoxemic patient. The inlet end 39e may have a boot adapter assembly to accommodate the boot of any commercially available MDI and the MDI 24e maybe alternatively be connected to the inlet end 39e of the tube and on actuation the aerosol particles generated by the MDI will be transferred from the nebulizer chamber 4e to the MDI chamber .The inhaler 24e has a boot 25e with an inlet end 26e and an outlet end 27e.A

canister 28e is introduced into the boot 25e through the inlet end 26e and the nozzle 29e of the MDI 24e is attached to an actuator 30e. The actuator 30e has an opening or an aperture 31e. On actuation of the MDI canister 28e, the medication aerosol particles are generated through the opening 31e of the actuator 30e.

The nebulizer chamber has an inlet port 52e for connection with a standard small volume nebulizer 53e. The aerosol medication generated with the nebulizer 53e can enter the MDI chamber via a central connection between the MDI chamber and the nebulizer chamber 2e6e. Chamber 4e also has another inlet 54e for connection to a reservoir bag 55e. The reservoir bag 55e serves to store the aerosol particles generated by the nebulizer 53e during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The bag 55e has two small inlets 56e and 57e to be connected to one or more gas sources to obtain a mixture of gases with a desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

Fig 1F is a plan view of the longitudinal length of aerosol delivery apparatus IV according to the second alternative embodiment of the present invention. Figure 1F is a perspective view of the invention that may be used with both a metered dose inhaler (MDI) or a nebulizer. The MDI chamber 1a has an outlet end 3f.The nebulizer chamber 4f has an inlet end 5f. The inlet end of the MDI chamber 1f and the outlet end of the nebulizer chamber 4f are fused together, the point of fusion is labeled as 2f6f. The outlet end 3f of the MDI chamber 1f has a hollow cylindrical tube 16f with an inlet end 17f and an outlet end 18f. The MDI chamber 1f may be made of plastic, paper, or metal. The chamber 1f may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with

smooth edges or cylindrical with multiple ridges 19f and grooves 20f.The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 21f of the coil are demonstrated in the figure as dotted lines. **The chamber 1f in this figure is demonstrated to be fully or partially collapsed**. The distance 22f and 23f between the two adjacent ridges, rings of the coil, or grooves is reduced by pulling the rings of the coil, ridges or grooves together. When fully collapsed, the inlet end 17f of the tube 16f may be fused to the outlet end 9f of the tube 7f. The distance 22f and 23f between the two adjacent ridges, rings of the coil, or grooves may be equal.

The outlet tube 16f of the MDI chamber 1f has two valve assemblies disposed between the inlet end 17f and the outlet end 18f –the inhalation valve assembly and an exhalation valve assembly .The inhalation flap valve assembly has a circular flap valve seat 32f that has a circular opening 33f and a flap valve 34f as demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 35f that has a circular opening 36f and a flap valve 37f as demonstrated by the dotted line. On inhalation, the inhalation flap valve 34f moves away from the valve seat 32f for the aerosol particles to move from the MDI chamber 1f to the patient through the opening 33f in the valve seat 32f of the tube 16f. On exhalation, the flap valve 34f moves towards the flap valve seat 32f and closes the opening 33f to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 1f thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 32f prevents any protrusion of the flap valve 34f through the opening 33f. The exhalation flap valve assembly has a flap valve 37f that presses against the flap valve seat 35f on inhalation and completely occludes the opening 36f to prevent any room air entrainment i.e. not

allowing the air from the atmosphere to enter into the tube 16f on inhalation. On exhalation the flap valve 37f moves away from the flap valve seat 35f for the air exhaled by the patient to escape into the atmosphere from tube 16f through the opening 36f.

The nebulizer chamber 4f has a hollow cylindrical inlet tube 38f with an inlet end 39f and an outlet end 40f. The inlet and 39f can be attached to a single or multiple gas sources to obtain a mixture of gases with a desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles and /or to deliver a fixed concentration of oxygen to a hypoxemic patient. The inlet end 39f may have a boot adapter assembly to accommodate the boot of any commercially available MDI and the MDI 24f maybe alternatively be connected to the inlet end 39f of the tube and on actuation the aerosol particles generated by the MDI will be transferred from the nebulizer chamber 4f to the MDI chamber .The inhaler 24f has a boot 25f with an inlet end 26f and an outlet end 27f.A canister 28f is introduced into the boot 25f through the inlet end 26f and the nozzle 29f of the MDI 24f is attached to an actuator 30f. The actuator 30f has an opening or an aperture 31f. On actuation of the MDI canister 28f, the medication aerosol particles are generated through the opening 31f of the actuator 30f.

The nebulizer chamber has an inlet port 52f for connection with a standard small volume nebulizer 53f. The aerosol medication generated with the nebulizer 53f can enter the MDI chamber via a central connection between the MDI chamber and the nebulizer chamber 2f6f. Chamber 4f also has another inlet 54f for connection a reservoir bag 55f. The reservoir bag 55f serves to store the aerosol particles generated by the nebulizer 53f during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The bag 55f has two small inlets 56f and 57f to be connected to one or more gas sources to obtain a mixture of

gases with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

Fig 2A is a plan view of the longitudinal length of aerosol delivery apparatus IV according to the third alternative embodiment of the present invention. Figure 2A is a plan view of the invention that may be used with a metered dose inhaler (MDI) or a nebulizer. The illustration here is describes the use of this device preferentially with an MDI. The device has two hollow chambers, a metered dose inhaler chamber 58a, and a nebulizer chamber 61a. The MDI chamber 58a has an inlet end 59a and an outlet end 60a.The nebulizer chamber 61a similarly has an inlet end 62a and an outlet end 63a. The inlet end 59a has three hollow cylindrical inlet tubes, a central tube 64a and two peripheral tubes 67a and 70a located at three o'clock to nine o'clock positions. The central hollow cylindrical tube 64a has an inlet end 65a and an outlet end 66a .The peripheral tube 67a has an inlet end 68a and an outlet end 69a and the peripheral tube 70a similarly has an inlet end 71a and an outlet ed 72a. The outlet end 60a of the MDI chamber 58a has a hollow cylindrical tube 73a with an inlet end 74a and an outlet end 75a. The MDI chamber 58a may be made of plastic, paper, or metal. The chamber 58a may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 76a and grooves 77a.The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 21a of the coil are demonstrated in the figure as dotted lines. The distance 79a and 80a between the two adjacent ridges, rings of the coil, or grooves may be equal. **The MDI chamber 58a and the nebulizer chamber 61a in this figure are illustrated as fully expanded.** The inlet end 65a of the tube 64a is

attached to the outlet end 84a of the boot 82a of a metered dose inhaler 81a. The inhaler 81a has a boot 82a with an inlet end 83a and an outlet end 84a.A canister 85a is introduced into the boot 82a through the inlet end 83a and the nozzle 86a of the MDI 81a is attached to an actuator 87a. The actuator 87a has an opening or an aperture 88a. On actuation of the MDI canister 85a, the medication aerosol particles are generated through the opening 88a of the actuator 87a, and enter into the chamber 58 through the outlet end 66a of the tube 64a.

The outlet tube 73a of the MDI chamber 58a has two valve assemblies disposed between the inlet end 74a and the outlet end 75a –the inhalation valve assembly and an exhalation valve assembly .The inhalation flap valve assembly has a circular flap valve seat 89a that has a circular opening 90a and a flap valve 91a as demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 92a that has a circular opening 93a and a flap valve 94a as demonstrated by the dotted line. On inhalation, the inhalation flap valve 91a moves away from the valve seat 89a for the aerosol particles to move from the MDI chamber 58a to the patient through the opening 90a in the valve seat 89a of the tube 73a. On exhalation, the flap valve 91a moves towards the flap valve seat 89a and closes the opening 90a to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 58a thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 89a prevents any protrusion of the flap valve 91a through the opening 90a. The exhalation flap valve assembly has a flap valve 94a that presses against the flap valve seat 92a on inhalation and completely occludes the opening 93a to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the tube 73a on inhalation. On exhalation the flap valve 94a moves away from the flap valve seat 92a for the air exhaled by the patient to escape into the atmosphere from tube 73a through the opening 93a.

The nebulizer chamber 61a has a hollow cylindrical outlet tube 98a that has an inlet end 99a and an outlet end 100a.The outlet end 100a may remain plugged with a cap when the device is in use with a metered dose inhaler. The nebulizer chamber also has two hollow cylindrical tubes, 101a and 104a, at three o'clock and nine o'clock positions. Tube 101a has an inlet end 102a and an outlet end 103a, whereas the tube 104a has an inlet end 105a and an outlet end 106a. The inlet end 68a of the tube 67a is connected to the outlet end 103a of the tube 101a with a collapsible/expandable stiff corrugated plastic tubing 107a and similarly the inlet end 71a of tube 70a is connected to the outlet end 106a of tube 104a with a collapsible/expandable corrugated plastic tubing 108a. The collapsible/expandable tubings 107a and 108a are demonstrated to be fully expanded in figure 1A to accommodate MDI boot 82a between the MDI chamber 1a and the nebulizer chamber 61a. The nebulizer chamber has an inlet port 109a for connection with a standard small volume nebulizer 110a.

Nebulizer chamber 61a may have another inlet 111a for connection to a reservoir bag 112a. The bag 112a may have two small inlets 113a and 114a to be connected to one or more gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient. Alternatively, the reservoir bag 112a may be replaced by a corrugated plastic reservoir tubing or chamber 115a that may be connected to inlet 111a or to the inlet end 62a of the nebulizer chamber 61a. The reservoir tubing/chamber 115a may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 116a and grooves 117a.The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 118a of the coil are

demonstrated in the figure as dotted lines. The distance 119a and 120a between the two adjacent ridges, rings of the coil, or grooves may be equal .The reservoir bag 112a or reservoir tubing 115a serves to store the aerosol particles generated by the nebulizer 110a during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The reservoir tubing has an inlet end 121a that may have a hollow cylindrical inlet tube 95a with an inlet end 96a and an outlet end 97a.The inlet and 96a can be attached to a single or multiple gas sources to obtain a mixture of gases with a desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

Fig 2B is a plan view of the longitudinal length of aerosol delivery apparatus IV according to the third alternative embodiment of the present invention. Figure 2B is a plan view of the invention that may be used with a metered dose inhaler (MDI) or a nebulizer. The illustration here is describes the use of this device preferentially with an MDI. The device has two hollow chambers, a metered dose inhaler chamber 58b, and a nebulizer chamber 61b. The MDI chamber 58b has an inlet end 59b and an outlet end 60b.The nebulizer chamber 61b similarly has an inlet end 62b and an outlet end 63b. The inlet end 59b has three hollow cylindrical inlet tubes, a central tube 64b and two peripheral tubes 67b and 70b located at three o'clock to nine o'clock positions. The central hollow cylindrical tube 64b has an inlet end 65b and an outlet end 66b .The peripheral tube 67b has an inlet end 68b and an outlet end 69b and the peripheral tube 70b similarly has an inlet end 71b and an outlet ed 72b. The outlet end 60b of the MDI chamber 58b has a hollow cylindrical tube 73b with an inlet end 74b and an outlet end 75b. The MDI chamber 58b may be made of plastic, paper, or metal. The chamber 58b

may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 76b and grooves 77b.The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 78b of the coil are demonstrated in the figure as dotted lines. The chamber in this figure is demonstrated to be fully or partially collapsed. The distance 79b and 80b between the two adjacent ridges, rings of the coil, or grooves is reduced by pulling the rings of the coil, ridges or grooves together. When fully collapsed, the inlet end 74b of the tube 73b may be fused to the outlet end 66b of the tube 64b.The distance 79a and 80a between the two adjacent ridges, rings of the coil, or grooves may be equal. **The MDI chamber 58b and the nebulizer chamber 61b in this figure are illustrated as fully or partially collapsed.** The inlet end 65b of the tube 64b is attached to the outlet end 84b of the boot 82b of a metered dose inhaler 81b. The inhaler 81b has a boot 82b with an inlet end 83b and an outlet end 84b. A canister 85b is introduced into the boot 82b through the inlet end 83b and the nozzle 86b of the MDI 81b is attached to an actuator 87b. The actuator 87b has an opening or an aperture 88b. On actuation of the MDI canister 85b, the medication aerosol particles are generated through the opening 88b of the actuator 87b, and enter into the chamber 58 through the outlet end 66b of the tube 64b.

The outlet tube 73b of the MDI chamber 58b has two valve assemblies disposed between the inlet end 74b and the outlet end 75b –the inhalation valve assembly and an exhalation valve assembly .The inhalation flap valve assembly has a circular flap valve seat 89b that has a circular opening 90b and a flap valve 91b as demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 92b that has a circular opening 93b and a flap valve 94b as demonstrated by the dotted line. On inhalation, the inhalation flap

valve 91b moves away from the valve seat 89b for the aerosol particles to move from the MDI chamber 58b to the patient through the opening 90b in the valve seat 89b of the tube 73b. On exhalation, the flap valve 91b moves towards the flap valve seat 89b and closes the opening 90b to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 58b thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 89b prevents any protrusion of the flap valve 91b through the opening 90b. The exhalation flap valve assembly has a flap valve 94b that presses against the flap valve seat 92b on inhalation and completely occludes the opening 93b to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the tube 73b on inhalation. On exhalation the flap valve 94b moves away from the flap valve seat 92b for the air exhaled by the patient to escape into the atmosphere from tube 73b through the opening 93b.
The nebulizer chamber 61b has a hollow cylindrical inlet tube 95b with an inlet end 96b and an outlet end 97b. The inlet and 96b can be attached to a single or multiple gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

The nebulizer chamber 61b has a hollow cylindrical outlet tube 98b that has an inlet end 99b and an outlet end 100b.The outlet end 100b may remain plugged with a cap when the device is in use with a metered dose inhaler. The nebulizer chamber also has two hollow cylindrical tubes, 101b and 104b, at three o'clock and nine o'clock positions. Tube 101b has an inlet end 102b and an outlet end 103b, whereas the tube 104b has an inlet end 105b and an outlet end 106b. The inlet end 68b of the tube 67b is connected to the outlet end 103b of the tube 101b with a collapsible/expandable stiff corrugated plastic tubing 107b and similarly the inlet end 71b of tube 70b is connected to the outlet end 106b of tube 104b with a

collapsible/expandable corrugated plastic tubing 108b. The collapsible/expandable tubings 107b and 108b are demonstrated to be fully expanded in figure 1A to accommodate MDI boot 82b between the MDI chamber 1b and the nebulizer chamber 61b. The nebulizer chamber has an inlet port 109a for connection with a standard small volume nebulizer 110b.

Nebulizer chamber 61b may have another inlet 111b for connection to a reservoir bag 112b. The bag 112b may have two small inlets 113b and 114b to be connected to one or more gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient. Alternatively, the reservoir bag 112b may be replaced by a corrugated plastic reservoir tubing/chamber 115b that may be connected to inlet 111b or to the inlet end 62b of the nebulizer chamber 61b. The reservoir tubing/chamber 115b may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 116b and grooves 117b.The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 118b of the coil are demonstrated in the figure as dotted lines. The distance 119b and 120b between the two adjacent ridges, rings of the coil, or grooves may be equal .The reservoir bag 112b or reservoir tubing 115b serves to store the aerosol particles generated by the nebulizer 110b during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The reservoir tubing has an inlet end 121b that may have a hollow cylindrical inlet tube 95b with an inlet end 96b and an outlet end 97b.The inlet and 96b can be attached to a single or multiple gas sources to obtain a mixture of gases with desired density, oxygen concentration,

viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

Fig 2C is a plan view of the longitudinal length of aerosol delivery apparatus IV according to the fourth alternative embodiment of the present invention. Figure 2C is a plan view of the invention that may be used with a metered dose inhaler (MDI) or a nebulizer. The illustration here is describes the use of this device preferentially with an MDI. The device has two hollow chambers, a metered dose inhaler chamber 58c, and a nebulizer chamber 61c. The MDI chamber 58c has an inlet end 59c and an outlet end 60c.The nebulizer chamber 61c similarly has an inlet end 62c and an outlet end 63c. The inlet end 59c has three hollow cylindrical inlet tubes, a central tube 64c and two peripheral tubes 67c and 70c located at three o'clock to nine o'clock positions. The central hollow cylindrical tube 64c has an inlet end 65c and an outlet end 66c .The peripheral tube 67c has an inlet end 68c and an outlet end 69c and the peripheral tube 70c similarly has an inlet end 71c and an outlet ed 72c. The outlet end 60c of the MDI chamber 58c has a hollow cylindrical tube 73c with an inlet end 74c and an outlet end 75c. The MDI chamber 58c may be made of plastic, paper, or metal. The chamber 58c may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 76c and grooves 77c. The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 78c of the coil are demonstrated in the figure as dotted lines. The distance 79c and 80c between the two adjacent ridges, rings of the coil, or grooves may be equal. **The MDI chamber 58c and the nebulizer chamber 61c in this figure are illustrated as fully expanded .**The inlet end 65c of the tube 64c is not attached to the MDI 81c as demonstrated in figure 1A. The MDI 81c is demonstrated

separately in this figure. The inhaler 81c has a boot 82c with an inlet end 83c and an outlet end 84c.A canister 85c is introduced into the boot 82c through the inlet end 83c and the nozzle 86c of the MDI 81c is attached to an actuator 87c. The actuator 87c has an opening or an aperture 88c. On actuation of the MDI canister 85c, the medication aerosol particles are generated through the opening 88c of the actuator 87c.

The outlet tube 73c of the MDI chamber 58a has two valve assemblies disposed between the inlet end 74c and the outlet end 75c –the inhalation valve assembly and an exhalation valve assembly .The inhalation flap valve assembly has a circular flap valve seat 89c that has a circular opening 90c and a flap valve 91c as demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 92c that has a circular opening 93c and a flap valve 94c as demonstrated by the dotted line. On inhalation, the inhalation flap valve 91c moves away from the valve seat 89c for the aerosol particles to move from the MDI chamber 58c to the patient through the opening 90c in the valve seat 89c of the tube 73c. On exhalation, the flap valve 91c moves towards the flap valve seat 89c and closes the opening 90c to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 58c thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 89c prevents any protrusion of the flap valve 91c through the opening 90c. The exhalation flap valve assembly has a flap valve 94c that presses against the flap valve seat 92c on inhalation and completely occludes the opening 93c to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the tube 73c on inhalation. On exhalation the flap valve 94c moves away from the flap valve seat 92c for the air exhaled by the patient to escape into the atmosphere from tube 73c through the opening 93c.

The nebulizer chamber 61c has a hollow cylindrical inlet tube 95c with an inlet end 96c and an outlet end 97c. The inlet and 96c can be attached to a single or multiple gas sources to

obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

The nebulizer chamber 61c has a hollow cylindrical outlet tube 98c that has an inlet end 99c and an outlet end 100c. The nebulizer chamber also has two hollow cylindrical tubes, 101c and 104c, at three o'clock and nine o'clock positions. Tube 101c has an inlet end 102c and an outlet end 103c, whereas the tube 104c has an inlet end 105c and an outlet end 106c. The inlet end 68c of the tube 67c is connected to the outlet end 103c of the tube 101c with a collapsible/expandable stiff corrugated plastic tubing 107c and similarly the inlet end 71c of tube 70c is connected to the outlet end 106c of tube 104c with a collapsible/expandable corrugated plastic tubing 108c. Quite unlike figure 2A the collapsible/expandable tubings 107c and 108c are now demonstrated to be collapsed but still fully patent. The inlet end 66c of the tube 64c is now fused to the outlet end 100c of the tube 98c .The inlet end s 68c and 71c may be fused to the outlet ends 103c and 106c respectively or may stay separated .The nebulizer chamber has an inlet port 109c for connection with a standard small volume nebulizer 110c. The aerosol medication generated with the nebulizer 110c can enter the MDI chamber via a central connection between the tubes 60c and 98c or through the peripheral connections between the tubes 67c and 101c, and 70c and 104c.

Nebulizer chamber 61c may have another inlet 111c for connection to a reservoir bag 112c. The bag 112c may have two small inlets 113c and 114c to be connected to one or more gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient. Alternatively, the reservoir bag 112c may be replaced by a corrugated plastic reservoir tubing/chmaber 115c that may be connected to inlet

111c or to the inlet end 62c of the nebulizer chamber 61c. The reservoir tubing/chamber 115c may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 116c and grooves 117c. The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 118c of the coil are demonstrated in the figure as dotted lines. The distance 119c and 120c between the two adjacent ridges, rings of the coil, or grooves may be equal .The reservoir bag 112c or reservoir tubing 115c serves to store the aerosol particles generated by the nebulizer 110c during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The reservoir tubing has an inlet end 121c that may have a hollow cylindrical inlet tube 95c with an inlet end 96c and an outlet end 97c. The inlet end 96c can be attached to a single or multiple gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the

The MDI 81c can be connected to the inlet 97c and on actuation the aerosol particles generated by the MDI will be transferred from the nebulizer chamber 61c to the MDI chamber 58c via the central and two peripheral connections between the two chambers as described before. On actuation of the MDI canister 85c, the medication aerosol particles are generated through the opening 88c of the actuator 87c, and enter into the chamber 58 through the outlet end 66c of the tube 64c.

Fig 2D is a plan view of the longitudinal length of aerosol delivery apparatus IV according to the fourth alternative embodiment of the present invention. Figure 2D is a plan view of the invention that may be used with a metered dose inhaler (MDI) or a nebulizer. The

illustration here is describes the use of this device preferentially with an MDI. The device has two hollow chambers, a metered dose inhaler chamber 58d, and a nebulizer chamber 61d. The MDI chamber 58d has an inlet end 59d and an outlet end 60d.The nebulizer chamber 61d similarly has an inlet end 62d and an outlet end 63d. The inlet end 59d has three hollow cylindrical inlet tubes, a central tube 64d and two peripheral tubes 67d and 70d located at three o'clock to nine o'clock positions. The central hollow cylindrical tube 64d has an inlet end 65d and an outlet end 66d .The peripheral tube 67d has an inlet end 68d and an outlet end 69d and the peripheral tube 70d similarly has an inlet end 71d and an outlet end 72d. The outlet end 60d of the MDI chamber 58d has a hollow cylindrical tube 73d with an inlet end 74d and an outlet end 75d. The MDI chamber 58d may be made of plastic, paper, or metal. The chamber 58d may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 76d and grooves 77d. The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 78d of the coil are demonstrated in the figure as dotted lines. The chamber in this figure is demonstrated to be fully or partially collapsed. The distance 79d and 80d between the two adjacent ridges, rings of the coil, or grooves is reduced by pulling the rings of the coil, ridges or grooves together. **The MDI chamber 58d and the nebulizer chamber 61d in this figure are illustrated as fully collapsed.** When fully collapsed, the inlet end 74d of the tube 73d may be fused to the outlet end 66d of the tube 64d.The distance 79d and 80d between the two adjacent ridges, rings of the coil, or grooves may be equal. The inlet end 65d of the tube 64a is not attached to the MDI 81d as demonstrated in figure1A. The MDI 81d is demonstrated separately in this figure. The inhaler 81d has a boot 82d with an inlet end 83d and an outlet

end 84d. A canister 85d is introduced into the boot 82d through the inlet end 83d and the nozzle 86d of the MDI 81d is attached to an actuator 87d. The actuator 87d has an opening or an aperture 88d. On actuation of the MDI canister 85d, the medication aerosol particles are generated through the opening 88ad of the actuator 87d.

The outlet tube 73d of the MDI chamber 58d has two valve assemblies disposed between the inlet end 74d and the outlet end 75d –the inhalation valve assembly and an exhalation valve assembly .The inhalation flap valve assembly has a circular flap valve seat 89d that has a circular opening 90d and a flap valve 91d as demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 92d that has a circular opening 93d and a flap valve 94d as demonstrated by the dotted line. On inhalation, the inhalation flap valve 91d moves away from the valve seat 89d for the aerosol particles to move from the MDI chamber 58d to the patient through the opening 90d in the valve seat 89d of the tube 73d. On exhalation, the flap valve 91d moves towards the flap valve seat 89d and closes the opening 90d to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 58d thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 89d prevents any protrusion of the flap valve 91d through the opening 90d. The exhalation flap valve assembly has a flap valve 94d that presses against the flap valve seat 92d on inhalation and completely occludes the opening 93d to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the tube 73d on inhalation. On exhalation the flap valve 94d moves away from the flap valve seat 92d for the air exhaled by the patient to escape into the atmosphere from tube 73d through the opening 93d.

The nebulizer chamber 61d has a hollow cylindrical inlet tube 95d with an inlet end 96d and an outlet end 97d. The inlet and 96d can be attached to a single or multiple gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and

humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient. The nebulizer chamber 61d has a hollow cylindrical outlet tube 98d that has an inlet end 99d and an outlet end 100d. The nebulizer chamber also has two hollow cylindrical tubes, 101d and 104d, at three o'clock and nine o'clock positions. Tube 101d has an inlet end 102d and an outlet end 103d, whereas the tube 104d has an inlet end 105d and an outlet end 106d. The inlet end 68d of the tube 67d is connected to the outlet end 103d of the tube 101d with a collapsible/expandable stiff corrugated plastic tubing 107d and similarly the inlet end 71d of tube 70d is connected to the outlet end 106d of tube 104d with a collapsible/expandable corrugated plastic tubing 108d. . Quite unlike figure 2A the collapsible/expandable tubings 107d and 108d are now demonstrated to be collapsed but still fully patent. The inlet end 66d of the tube 64d is now fused to the outlet end 100d of the tube 98d. The inlet ends 68d and 71d may be fused to the outlet ends 103d and 106d respectively or may stay separated. The nebulizer chamber has an inlet port 109d for connection with a standard small volume nebulizer 110d. The aerosol medication generated with the nebulizer 110d can enter the MDI chamber via a central connection between the tubes 60d and 98d or through the peripheral connections between the tubes 67d and 101d, and 70d and 104d.

Nebulizer chamber 61d may have another inlet 111d for connection to a reservoir bag 112d. The bag 112d may have two small inlets 113d and 114d to be connected to one or more gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient. Alternatively, the reservoir bag 112d may be replaced by a corrugated plastic reservoir tubing/chamber 115d that may be connected to inlet 111d or to the inlet end 62d of the nebulizer chamber 61d. The reservoir tubing/chamber 115d may be a fixed volume chamber or a collapsible/expandable chamber. The chamber

may be cylindrical with smooth edges or cylindrical with multiple ridges 116d and grooves 117d.The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 118d of the coil are demonstrated in the figure as dotted lines. The distance 119d and 120d between the two adjacent ridges, rings of the coil, or grooves may be equal .The reservoir bag 112d or reservoir tubing 115d serves to store the aerosol particles generated by the nebulizer 110d during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The reservoir tubing has an inlet end 121d that may have a hollow cylindrical inlet tube 95d with an inlet end 96d and an outlet end 97d. The inlet and 96d can be attached to a single or multiple gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the

The MDI 81d can be connected to the inlet 97d and on actuation the aerosol particles generated by the MDI will be transferred from the nebulizer chamber 61d to the MDI chamber 58d via the central and two peripheral connections between the two chambers as described before. On actuation of the MDI canister 85d, the medication aerosol particles are generated through the opening 88d of the actuator 87d, and enter into the chamber 58 through the outlet end 66d of the tube 64d.

Fig 2E is a plan view of the longitudinal length of aerosol delivery apparatus IV according to the fifth alternative embodiment of the present invention. Figure 2E is a plan view of the invention that may be used with both a metered dose inhaler (MDI) or a nebulizer. The MDI chamber 58e has an outlet end 60e. The nebulizer chamber 61e has an inlet end 62e. The inlet end of the MDI chamber 58e and the outlet end of the nebulizer chamber 4e are fused together, the

point of fusion is labeled as 2e6e. The outlet end 60e of the MDI chamber 1e has a hollow cylindrical tube 73e with an inlet end 74e and an outlet end 75e. The MDI chamber 1e may be made of plastic, paper, or metal. The chamber 1e may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 76e and grooves 77. The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 78e of the coil are demonstrated in the figure as dotted lines. The distance 79e and 80e between the two adjacent ridges, rings of the coil, or grooves may be equal. **The MDI chamber 58e and the nebulizer chamber 61e in this figure are illustrated as fully expanded.**

The outlet tube 73e of the MDI chamber 58e has two valve assemblies disposed between the inlet end 74e and the outlet end 75e –the inhalation valve assembly and an exhalation valve assembly. The inhalation flap valve assembly has a circular flap valve seat 89e that has a circular opening 90e and a flap valve 91e as demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 92e that has a circular opening 93e and a flap valve 94e as demonstrated by the dotted line. On inhalation, the inhalation flap valve 91e moves away from the valve seat 89e for the aerosol particles to move from the MDI chamber 58e to the patient through the opening 90e in the valve seat 89e of the tube 73e. On exhalation, the flap valve 91e moves towards the flap valve seat 89e and closes the opening 90e to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 58e thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 89e prevents any protrusion of the flap valve 91e through the opening 90e. The exhalation flap valve assembly has a flap valve 94e that presses against the flap valve seat 92e on inhalation

and completely occludes the opening 93e to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the tube 73e on inhalation. On exhalation the flap valve 94e moves away from the flap valve seat 92e for the air exhaled by the patient to escape into the atmosphere from tube 73e through the opening 93e.

The nebulizer chamber 61e has a hollow cylindrical inlet tube 95e with an inlet end 96e and an outlet end 97a. The inlet and 96e can be attached to a single or multiple gas sources to obtain a mixture of gases with a desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles and /or to deliver a fixed concentration of oxygen to a hypoxemic patient. The inlet end 96e may have a boot adapter assembly to accommodate the boot of any commercially available MDI and the MDI 81e maybe alternatively be connected to the inlet end 96e of the tube and on actuation the aerosol particles generated by the MDI will be transferred from the nebulizer chamber 61e to the MDI chamber .The inhaler 81e has a boot 82e with an inlet end 83e and an outlet end 84e. A canister 85e is introduced into the boot 82e through the inlet end 83e and the nozzle 86e of the MDI 81a is attached to an actuator 87e. The actuator 87e has an opening or an aperture 88e. On actuation of the MDI canister 85e, the medication aerosol particles are generated through the opening 88e of the actuator 87e.

The nebulizer chamber has an inlet port 109e for connection with a standard small volume nebulizer 110e. The aerosol medication generated with the nebulizer 110e can enter the MDI chamber via a central connection between the MDI chamber and the nebulizer chamber 59e63e. Nebulizer chamber 61e may have another inlet 111e for connection to a reservoir bag 112e. The bag 112e may have two small inlets 113e and 114e to be connected to one or more gas sources to obtain a mixture of gases with a desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as

deliver a fixed concentration of oxygen to a hypoxemic patient. Alternatively, the reservoir bag 112e may be replaced by a corrugated plastic reservoir tubing/chamber 115e that may be connected to inlet 111e or to the inlet end 62e of the nebulizer chamber 61e. The reservoir tubing/chamber 115e may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 116e and grooves 117e. The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 118e of the coil are demonstrated in the figure as dotted lines. The distance 119e and 120e between the two adjacent ridges, rings of the coil, or grooves may be equal. The reservoir bag 112e or reservoir tubing 115e serves to store the aerosol particles generated by the nebulizer 110e during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The reservoir tubing has an inlet end 121e that may have a hollow cylindrical inlet tube 95e with an inlet end 96a and an outlet end 97e. The inlet end 96e can be attached to a single or multiple gas sources to obtain a mixture of gases with a desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient. The MDI 81e can be connected to the inlet 97e and on actuation the aerosol particles generated by the MDI will be transferred from the nebulizer chamber 61e to the MDI chamber 58e via the central and two peripheral connections between the two chambers as described before. On actuation of the MDI canister 85e, the medication aerosol particles are generated through the opening 88e of the actuator 87e, and enter into the chamber 58e through the outlet end 66e of the tube 64e.

Fig 2F is a plan view of the longitudinal length of aerosol delivery apparatus IV according to the fifth alternative embodiment of the present invention. Figure 2F is a plan view of the invention that may be used with both a metered dose inhaler (MDI) or a nebulizer. The MDI chamber 58f has an outlet end 60f. The nebulizer chamber 61f has an inlet end 62f. The inlet end of the MDI chamber 58f and the outlet end of the nebulizer chamber 4f are fused together, the point of fusion is labeled as 2f6f. The outlet end 60f of the MDI chamber 1f has a hollow cylindrical tube 73f with an inlet end 74f and an outlet end 75f. The MDI chamber 1f may be made of plastic, paper, or metal. The chamber 1f may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 76f and grooves 77. The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 78f of the coil are demonstrated in the figure as dotted lines. The chamber in this figure is demonstrated to be fully or partially collapsed. The distance 79f and 80f between the two adjacent ridges, rings of the coil, or grooves is reduced by pulling the rings of the coil, ridges or grooves together. **The MDI chamber 58f and the nebulizer chamber 61f in this figure are illustrated as fully collapsed.** When fully collapsed, the inlet end 74f of the tube 73f may be fused to the outlet end 66f of the tube 64f. The distance 79f and 80f between the two adjacent ridges, rings of the coil, or grooves may be equal.

The outlet tube 73f of the MDI chamber 58f has two valve assemblies disposed between the inlet end 74f and the outlet end 75f –the inhalation valve assembly and an exhalation valve assembly .The inhalation flap valve assembly has a circular flap valve seat 89f that has a circular opening 90f and a flap valve 91f as demonstrated by the dotted line.

The exhalation valve assembly has a circular flap valve seat 92f that has a circular opening 93f and a flap valve 94f as demonstrated by the dotted line. On inhalation, the inhalation flap valve 91f moves away from the valve seat 89f for the aerosol particles to move from the MDI chamber 58f to the patient through the opening 90f in the valve seat 89f of the tube 73f. On exhalation, the flap valve 91f moves towards the flap valve seat 89f and closes the opening 90f to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 58f thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 89f prevents any protrusion of the flap valve 91f through the opening 90f. The exhalation flap valve assembly has a flap valve 94f that presses against the flap valve seat 92f on inhalation and completely occludes the opening 93f to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the tube 73f on inhalation. On exhalation the flap valve 94f moves away from the flap valve seat 92f for the air exhaled by the patient to escape into the atmosphere from tube 73f through the opening 93f.

The nebulizer chamber 61f has a hollow cylindrical inlet tube 95f with an inlet end 96f and an outlet end 97f. The inlet and 96f can be attached to a single or multiple gas sources to obtain a mixture of gases with a desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles and /or to deliver a fixed concentration of oxygen to a hypoxemic patient. The inlet end 96f may have a boot adapter assembly to accommodate the boot of any commercially available MDI and the MDI 81f maybe alternatively be connected to the inlet end 96f of the tube and on actuation the aerosol particles generated by the MDI will be transferred from the nebulizer chamber 61f to the MDI chamber. The inhaler 81f has a boot 82f with an inlet end 83f and an outlet end 84f. A canister 85f is introduced into the boot 82f through the inlet end 83f and the nozzle 86f of the MDI 81f is attached to an actuator 87f. The actuator 87f has an opening or an aperture 88f.

On actuation of the MDI canister 85f, the medication aerosol particles are generated through the opening 88f of the actuator 87f.

The nebulizer chamber has an inlet port 109f for connection with a standard small volume nebulizer 110f. The aerosol medication generated with the nebulizer 110f can enter the MDI chamber via a central connection between the MDI chamber and the nebulizer chamber 59f63f. Nebulizer chamber 61f may have another inlet 111f for connection to a reservoir bag 112f. The bag 112f may have two small inlets 113f and 114f to be connected to one or more gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient. Alternatively, the reservoir bag 112f may be replaced by a corrugated plastic reservoir tubing/chamber 115f that may be connected to inlet 111f or to the inlet end 62f of the nebulizer chamber 61f. The reservoir tubing/chamber 115f may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 116f and grooves 117f. The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 118f of the coil are demonstrated in the figure as dotted lines. The distance 119f and 120f between the two adjacent ridges, rings of the coil, or grooves may be equal .The reservoir bag 112f or reservoir tubing 115f serves to store the aerosol particles generated by the nebulizer 110f during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The reservoir tubing has an inlet end 121f that may have a hollow cylindrical inlet tube 95f with an inlet end 96f and an outlet end 97f.The inlet and 96f can be attached to a single or multiple gas sources to

obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient. The MDI 81f can be connected to the inlet 97f and on actuation the aerosol particles generated by the MDI will be transferred from the nebulizer chamber 61f to the MDI chamber 58f via the central and two peripheral connections between the two chambers as described before. On actuation of the MDI canister 85f, the medication aerosol particles are generated through the opening 88f of the actuator 87f, and enter into the chamber 58 through the outlet end 66f of the tube 64f.

Figure 3A,3B,3C,3D,3E,and 3F are the plan views of the MDI chamber 1a as described in figure 1A.They also represent the plan views of the reservoir tubing or chamber 115a as described in figure 2A . The MDI chamber /reservoir chamber may be made of plastic, paper, or metal. The chamber(s) may be a fixed volume chamber or a collapsible/expandable chamber. The chamber(s) may have a uniform diameter throughout it's length or alternatively the diameter of the chamber may be uniform for a fixed portion of the total length of the chamber and then change to a different diameter for the rest of it's length. The chamber(s) may be cylindrical with smooth edges or cylindrical with multiple ridges and grooves. The chamber(s) may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber(s) may be supported with a metal or plastic coil with multiple rings. The distance and between the two adjacent ridges, rings of the coil, or grooves may be equal.

Fig 3A is an expanded plan view of MDI chamber 1a according to the present invention as described in Fig 1A. Figure 3A is an expanded plan view of the MDI chamber 1a as described in figure 1A. It is also an expanded plan view of the reservoir tubing or chamber 115a as described in figure 2A. The MDI chamber /reservoir chamber 122a may be

made of plastic, paper, or metal. The chamber(s) may be a fixed volume chamber or a collapsible/expandable chamber. The chamber has an inlet end 123a and an outlet end 124a .The chamber(s) has a uniform diameter throughout its length and is cylindrical in shape. It requires additional support with a metal or plastic coil with multiple rings to maintain patency of the chamber if it is collapsible /expandable and may not require any additional support to maintain patency of the chamber if it is a fixed volume chamber. **The MDI chamber 122a in this figure is illustrated as fully expanded.** The multiple rings125a of the coil are demonstrated in the figure as dotted lines. The distance between the two adjacent rings of the coil 126a and 127a may be equal.

Fig 3B is an expanded plan views of MDI chamber 1a according to the present invention as described in Fig 1A. Figure 3B is an expanded plan view of the MDI chamber/reservoir chamber 122a as described in figure 3A. The chamber(s) 122b is a collapsible/expandable chamber. The chamber has an inlet end 123b and an outlet end 124b. The chamber(s) has a uniform diameter throughout it's length and is cylindrical in shape. It requires additional support with a metal or plastic coil with multiple rings to maintain patency of the chamber if it is collapsible /expandable. **The MDI chamber 122b in this figure is illustrated as fully or partially collapsed.** The multiple rings 125b of the coil are demonstrated in the figure as dotted lines. The chamber as is demonstrated here may be partially collapsed by pulling some of the rings of the coil together or fully collapsed by pulling all of the rings of the coil together. The distance between the two adjacent rings of the coil 126b and 127b may be equal.

Fig 3C is an expanded plan view of MDI chamber 1a according the first alternative embodiment of the present invention as described in Fig 3A and Fig 3B. Figure 3C is an expanded plan view of the MDI chamber/reservoir chamber 122a as described in figure 3A.

The chamber(s) 122c may be a fixed volume chamber or a collapsible/expandable chamber. The chamber has an inlet end 123c and an outlet end 124c. The chamber(s) is cylindrical in shape but does not have a uniform diameter throughout it's length as described in figure 3A. It requires additional support with a metal or plastic coil with multiple rings to maintain patency of the chamber if it is collapsible /expandable and may not require any additional support to maintain patency of the chamber if it is a fixed volume chamber. **The MDI chamber 122c in this figure is illustrated as fully expanded** The multiple rings125c of the coil are demonstrated in the figure as dotted lines. The diameter of the chamber for a portion of the length 126c of the chamber is different from the diameter of a portion of the length 127c of the chamber. The diameter of the rings 128c that support a portion of the length 126c of the chamber is different from the diameter of the rings 129c that support a portion of the length 127c of the chamber. The distance between the two adjacent rings of the coil 130c and 131c may be equal. Similarly the distance between the two adjacent rings of the coil 132c and 133c may be equal. The multiple rings 125c of the coil are demonstrated in the figure as dotted lines. The chamber here is demonstrated to be fully expanded but it may be partially collapsed by pulling some of the rings of the coil together or fully collapsed by pulling all of the rings of the coil together.

Fig 3D is and expanded plan view of MDI chamber 1a according to the second alternative embodiment of the present invention as described in Fig 3A and 3B. Figure 3D is a perspective view of the MDI chamber 1a as described in figure 1A.It is also a perspective view of the reservoir tubing or chamber 115a as described in figure 2A. The MDI chamber /reservoir chamber 122d may be made of plastic, paper, or metal. The chamber(s) may be a fixed volume chamber or a collapsible/expandable chamber. The chamber has an inlet end 123d and an outlet end 124d. The chamber(s) has a uniform diameter throughout it's length,

is cylindrical in shape with multiple ridges and grooves throughout the length of the chamber. It requires additional support with a metal or plastic coil with multiple rings to maintain patency of the chamber if it is collapsible /expandable and may not require any additional support to maintain patency of the chamber if it is a fixed volume chamber. **The MDI chamber 122d in this figure is illustrated as fully expanded.** The multiple rings 125d of the coil are demonstrated in the figure as dotted lines. The distance and between the two adjacent rings of the coil 126d and 127d may be equal.

Fig 3E is an expanded plan view of MDI chamber 1a according to the second alternative embodiment of the present invention as described in Fig 3A and 3B. Figure 3E is an expanded plan view of the MDI chamber/reservoir chamber 122d as described in figure 3D. The chamber(s) 122e is a collapsible/expandable chamber. The chamber has an inlet end 123e and an outlet end 124e. The chamber(s) has a uniform diameter throughout it's length and is cylindrical in shape. It requires additional support with a metal or plastic coil with multiple rings to maintain patency of the chamber if it is collapsible /expandable. **The MDI chamber 122e in this figure is illustrated as fully or partially collapsed.** The multiple rings 125e of the coil are demonstrated in the figure as dotted lines. The chamber may be partially collapsed by pulling some of the rings of the coil together or fully collapsed by pulling all of the rings of the coil together as has been demonstrated in this figure. The distance 126e and 127e between the two adjacent rings of the coil, the ridges, or the grooves may be equal.

Fig 3F is an expanded plan view of MDI chamber 1a according to the third alternative embodiment of the present invention as described in Fig 3A and 3B. Figure 3F is an expanded plan view of the MDI chamber/reservoir chamber 122d as described in figure 3D. The chamber(s) 122f may be a fixed volume chamber or a collapsible/expandable chamber.

The chamber has an inlet end 123f and an outlet end 124f. The chamber(s) is cylindrical in shape but does not have a uniform diameter throughout it's length as described in figure 3D. It requires additional support with a metal or plastic coil with multiple rings to maintain patency of the chamber if it is collapsible /expandable and may not require any additional support to maintain patency of the chamber if it is a fixed volume chamber. **The MDI chamber 122f in this figure is illustrated as fully expanded** The multiple rings 125f of the coil are demonstrated in the figure as dotted lines. The diameter of the chamber for a portion of the length 126f of the chamber is different from the diameter of a portion of the length 127f of the chamber. The diameter of the rings 128f that support a portion of the length 126f of the chamber is different from the diameter of the rings 129f that support a portion of the length 127f of the chamber. The distance and between the two adjacent rings of the coil 130f and 131f may be equal. Similarly the distance and between the two adjacent rings of the coil 132f and 133f may be equal. The multiple rings 125f of the coil are demonstrated in the figure as dotted lines. The chamber here is demonstrated to be fully expanded but it may be partially collapsed by pulling some of the rings of the coil together or fully collapsed by pulling all of the rings of the coil together.

Fig 3G is an expanded plan view of MDI chamber 1a according to the fourth alternative embodiment of the present invention as described in Fig 3A and 3B. Figure 3G is an expanded plan view of the MDI chamber 1a as described in figure 1A. It is also an alternative plan view of the reservoir tubing or chamber 115a as described in figure 2A. The MDI chamber /reservoir chamber 122g may be made of plastic, paper, or metal. The chamber(s) may be a fixed volume chamber or a collapsible/expandable chamber. The chamber has an inlet end 123a and an outlet end 124g .The chamber(s) has a uniform diameter throughout it's length, is cylindrical in shape with multiple ridges and grooves

throughout the length of the chamber. Quite unlike figure 3D, the chamber does not require additional support with a metal or plastic coil with multiple rings to maintain patency as it can be made of a stiff corrugated plastic material that retains the ability to be collapsible/expandable and at the same time not require any additional support to maintain patency of the chamber. **The MDI chamber 122g in this figure is illustrated as fully expanded** The distance between the two adjacent ridges or grooves 126g and 127g of the corrugated plastic tubing may be equal.

Fig 3H is an expanded plan views of MDI chamber 1a according to the fourth alternative embodiment of the present invention as described in Fig 3A and 3B. Figure 3H is an expanded plan view of the MDI chamber/reservoir chamber 122g as described in figure 3G. The chamber(s) 122h is a collapsible/expandable chamber. The chamber has an inlet end 123h and an outlet end 124h. The chamber(s) has a uniform diameter throughout it's length, is cylindrical in shape with multiple ridges and grooves throughout the length of the chamber. The chamber does not require additional support with a metal or plastic coil with multiple rings to maintain patency as it can be made of a stiff corrugated plastic material that retains the ability to be collapsible /expandable and at the same time not require any additional support to maintain patency of the chamber. **The MDI chamber 122h in this figure is illustrated as fully or partially collapsed.** The distance 126h and 127h between the two adjacent ridges/grooves of the corrugated plastic tubing may be equal.

Fig 3I is an expanded plan view of MDI chamber 1a according to the fifth alternative embodiment of the present invention as described in Fig 3A and 3B. Figure 3I is an expanded plan view of the MDI chamber/reservoir chamber 122g as described in figure 3G. The chamber(s) 122i may be a fixed volume chamber or a collapsible/expandable chamber. The chamber has an inlet end 123i and an outlet end 124i .The chamber(s) is cylindrical in shape

but quite unlike the description in figure 3G, the chamber in figure 3I does not have a uniform diameter throughout it's length. The chamber does not require additional support with a metal or plastic coil with multiple rings to maintain patency as it can be made of a stiff corrugated plastic material that retains the ability to be collapsible /expandable and at the same time not require any additional support to maintain patency of the chamber. **The MDI chamber 122i in this figure is illustrated as fully expanded** The diameter of the chamber for a portion of the length 126i of the chamber is different from the diameter of a portion of the length 127i of the chamber. The diameter of the ridges/grooves 128i of a portion of the length 126i of the chamber is different from the diameter of the ridges/grooves 129i of a portion of the length 127i of the chamber. The distance between the two adjacent ridges/grooves of the tubing 130i and 131i may be equal. Similarly the distance between the two adjacent ridges/grooves of the tubing 132i and 133i may be equal. The chamber here is demonstrated to be fully expanded but it may be partially collapsed by pulling some of the ridges/grooves of the tubing together or fully collapsed by pulling all of the ridges/grooves of the tubing together.

Figure 4A,4B,4C,4D,4E,and 4F are expanded plan views of the collapsible/expandable tubings 50a and 51a as described in figure 1A that connect the peripheral tubes at 3 and 9 o'clock positions in the inlet of MDI chamber to the peripheral tubes at 3 and 9 o' clock positions in the outlet of the nebulizer chamber . The tubing illustrated here may be made of plastic, paper, or metal. The tubing may be a fixed volume chamber or a collapsible/expandable chamber. The chamber(s) has a uniform diameter throughout it's length , is cylindrical with smooth edges or cylindrical in shape and made of stiff corrugated plastic material with multiple ridges and grooves. The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber(s) may be supported with a metal or plastic coil with

multiple rings. The distance and between the two adjacent ridges, rings of the coil, or grooves may be equal.

Fig 4A is an expanded plan view of tubes 50a or 51a according to the present invention as described in Fig 1A. Figure 4A is an expanded plan view of the collapsible/expandable tubings 50a and 51a as described in figure 1A that connects the peripheral tubes at 3 and 9 o'clock positions in the inlet of MDI chamber to the peripheral tubes at 3 and 9 o' clock positions in the outlet of the nebulizer chamber . The tubing illustrated here as 134a may be made of plastic, paper, or metal. The tubing may be a fixed volume chamber or a collapsible/expandable chamber. The chamber(s) has a uniform diameter throughout it's length, is cylindrical in shape with smooth edges. The chamber may be supported with a metal or plastic coil with multiple rings. **The tubing 134a in this figure is illustrated as fully expanded** The distance between the two adjacent rings of the coil may be equal. The chamber 134a connects the two hollow cylindrical tubes 135a and 138a. Tube 135a represents the expanded view of the tubes 10a and 13a and tube 138a represents the expanded view of the tubes 44a and 47a as shown in figure 1A. Tube 135a has an inlet end 136a and an outlet end 137a. Tube 138a has an inlet end 139a and an outlet end 140a. The points of attachments of the tubing 134a to the tube 135a is between the inlet 136a and outlet 137a and is demonstrated in the figure as 141a.. The points of attachments of the tubing 134a to the tube 138 is between the inlet 139 and outlet 140a and is demonstrated in the figure as 142a. The multiple rings143a of the coil are demonstrated in the figure as dotted lines. The distance and between the two adjacent rings of the coil 144a and 145a may be equal.

Fig 4B is an expanded plan view of tubes 50a or 51a according to the present invention as described in Fig 1A. Figure 4B is an expanded plan view of the collapsible/expandable tubings 50a and 51a as described in figure 1A that connect the

peripheral tubes at 3 and 9 o'clock positions in the inlet of the MDI chamber to the peripheral tubes at 3 and 9 o' clock positions in the outlet of the nebulizer chamber. The tubing illustrated here as 134b may be made of plastic, paper, or metal. The tubing may be a fixed volume chamber or a collapsible/expandable chamber. In this figure the tubing 134b is demonstrated as partially or fully collapsed. The chamber(s) has a uniform diameter throughout it's length, is cylindrical in shape with smooth edges. The chamber may be supported with a metal or plastic coil with multiple rings. **The tubing 134b in this figure is illustrated as fully or partially collapsed.** The distance and between the two adjacent ridges, rings of the coil, or grooves may be equal. The chamber or tubing 134b connects the two hollow cylindrical tubes 135b and 138b. Tube 135b represents the expanded view of the tubes 10a and 13a and tube 138b represents the expanded view of the tubes 44a and 47a as shown in figure 1A. Tube 135b has an inlet end 136b and an outlet end 137b. Tube 138b has an inlet end 139b and an outlet end 140b. The points of attachments of the tubing 134b to the tube 135b is between the inlet 136b and outlet 137b and is demonstrated in the figure as 141b. The points of attachments of the tubing 134b to the tube 138b is between the inlet 139b and outlet 140b and is demonstrated in the figure as 142b. The multiple rings143b of the coil are demonstrated in the figure as dotted lines. The chamber may be partially collapsed by pulling some of the rings of the coil together or fully collapsed by pulling all of the rings of the coil together as has been demonstrated in this figure. The distance between the two adjacent rings of the coil 144b and 145b may or may not be equal when partially collapsed. When fully collapsed, the inlet end 136b of the tube 135b may fuse or mate with the outlet end 140b of the outlet tube 138b.as has been demonstrated in this figure.

Fig 4C is an expanded plan view of tubes 50a or 51a according to the first alternative embodiment of the present invention as described in Fig 4A and 4B. Figure 4C is an

expanded plan_view of the collapsible/expandable tubings 50a and 51a as described in figure 1A that connect the peripheral tubes at 3 and 9 o'clock positions in the inlet of MDI chamber to the peripheral tubes at 3 and 9 o' clock positions in the outlet of the nebulizer chamber. The tubing illustrated here as 134c may be made of plastic, paper, or metal. The tubing may be a fixed volume chamber or a collapsible/expandable chamber. **The tubing 134c in this figure is illustrated as fully expanded** The chamber(s) has a uniform diameter throughout it's length, is cylindrical in shape with multiple ridges 146c and grooves 147c throughout the length of the chamber. It requires additional support with a metal or plastic coil with multiple rings to maintain patency of the chamber if it is collapsible/expandable and may not require any additional support to maintain patency of the chamber if it is a fixed volume chamber. The chamber 134c connects the two hollow cylindrical tubes135c and 138c. Tube 135c represents the expanded view of the tubes 10a and 13a and tube 138c represents the expanded view of the tubes 44a and 47a as shown in figure 1A. Tube 135c has an inlet end 136c and an outlet end 137c. Tube 138c has an inlet end 139c and an outlet end 140c. The points of attachments of the tubing 134c to the tube 135c is between the inlet 136c and outlet 137c and is demonstrated in the figure as 141c. The points of attachments of the tubing 134c to the tube 138c is between the inlet 139c and outlet 140c and is demonstrated in the figure as 142c. The multiple rings 143c of the coil are demonstrated in the figure as dotted lines. The distance 144c and 145c between the two adjacent rings of the coil 143c, the ridges 146c or the grooves 147c may be equal.

Fig 4D is an expanded plan view of tubes 50a or 51a according to the first alternative embodiment of the present invention as described in Fig 4A and 4B. Figure 4D is an expanded plan_view of the collapsible/expandable tubings 50a and 51 as described in figure 1A that connect the peripheral tubes at 3 and 9 o'clock positions in the inlet of MDI chamber

to the peripheral tubes at 3 and 9 o' clock positions in the outlet of the nebulizer chamber. The tubing illustrated here as 134d may be made of plastic, paper, or metal. The tubing may be a fixed volume chamber or a collapsible/expandable chamber. **In this figure the tubing 134d is demonstrated as partially or fully collapsed.** The chamber(s) has a uniform diameter throughout it's length, is cylindrical in shape with multiple ridges 146d and grooves 147d throughout the length of the chamber. It requires additional support with a metal or plastic coil with multiple rings to maintain patency of the chamber if it is collapsible /expandable and may not require any additional support to maintain patency of the chamber if it is a fixed volume chamber. The chamber 134d connects the two hollow cylindrical tubes 135d and 138d. Tube 135d represents the expanded view of the tubes 10a and 13a and tube 138d represents the expanded view of the tubes 44a and 47a as shown in figure 1A. Tube 135d has an inlet end 136d and an outlet end 137d. Tube 138d has an inlet end 139d and an outlet end 140d. The points of attachments of the tubing 134d to the tube 135d is between the inlet 136d and outlet 137d and is demonstrated in the figure as 141d. The points of attachments of the tubing 134d to the tube 138d is between the inlet 139d and outlet 140d and is demonstrated in the figure as 142d. The multiple rings143d of the coil are demonstrated in the figure as dotted lines. The chamber may be partially collapsed by pulling some of the rings of the coil together or fully collapsed by pulling all of the rings of the coil together as has been demonstrated in this figure. The distance 144d and 145d between the two adjacent rings of the coil 143d, the ridges 146d or the grooves 147d may or may not be equal when partially collapsed. When fully collapsed, the inlet end 136d of the tube 135d may fuse or mate with the outlet end 140d of the outlet tube 138d as has been demonstrated in this figure.

Fig 4E is an expanded plan view of tubes 50a or 51a according to the second alternative embodiment of the present invention as described in Fig 4A and 4B.

Figure 4E is an expanded plan view of the collapsible/expandable tubings 50a and 51a as described in figure 1A that connect the peripheral tubes at 3 and 9 o'clock positions in the inlet of MDI chamber to the peripheral tubes at 3 and 9 o' clock positions in the outlet of the nebulizer chamber. The tubing illustrated here as 134e may be made of plastic, paper, or metal. The tubing may be a fixed volume chamber or a collapsible/expandable chamber. **The tubing 134e in this figure is illustrated as fully expanded** The chamber(s) has a uniform diameter throughout it's length, is cylindrical in shape with multiple ridges 146e and grooves 147e throughout the length of the chamber. Quite unlike figure 4C, the chamber does not require additional support with a metal or plastic coil with multiple rings to maintain patency as it can be made of a stiff corrugated plastic material that retains the ability to be collapsible /expandable and at the same time not require any additional support to maintain patency of the chamber 134e connects the two hollow cylindrical tubes 135e and 138e. Tube 135e represents the expanded view of the tubes 10a and 13a and tube 138e represents the expanded view of the tubes 44a and 47a as shown in figure 1A. Tube 135e has an inlet end 136e and an outlet end 137e. Tube 138e has an inlet end 139e and an outlet end 140e. The points of attachments of the tubing 134e to the tube 135e is between the inlet 136e and outlet 137e and is demonstrated in the figure as 141e. The points of attachments of the tubing 134e to the tube 138e is between the inlet 139e and outlet 140e and is demonstrated in the figure as 142e. The multiple rings 143e of the coil are demonstrated in the figure as dotted lines. The distance 144e and 145e between the two adjacent rings of the coil 143e, the ridges 146e or the grooves 147e may be equal.

Fig 4F is an expanded plan view of tubes 50a or 51a according to the second alternative embodiment of the present invention as described in Fig 4A and 4B.

Figure 4F is an expanded plan view of the collapsible/expandable tubings 50a and 51a as described in figure 1A that connect the peripheral tubes at 3 and 9 o'clock positions in the inlet of MDI chamber to the peripheral tubes at 3 and 9 o' clock positions in the outlet of the nebulizer chamber. The tubing illustrated here as 134f may be made of plastic, paper, or metal. The tubing may be a fixed volume chamber or a collapsible/expandable chamber. **In this figure the tubing 134f is demonstrated as partially or fully collapsed.** The chamber(s) has a uniform diameter throughout it's length, is cylindrical in shape with multiple ridges 146f and grooves 147f throughout the length of the chamber. Quite unlike figure 4C, the chamber does not require additional support with a metal or plastic coil with multiple rings to maintain patency as it can be made of a stiff corrugated plastic material that retains the ability to be collapsible/expandable and at the same time not require any additional support to maintain patency of the chamber. The chamber 134f connects the two hollow cylindrical tubes 135f and 138f. Tube 135f represents the expanded view of the tubes 10a and 13a and tube 138f represents the expanded view of the tubes 44a and 47a as shown in figure 1A. Tube 135f has an inlet end 136f and an outlet end 137f. Tube 138f has an inlet end 139f and an outlet end 140f. The points of attachments of the tubing 134f to the tube 135f is between the inlet 136f and outlet 137f and is demonstrated in the figure as 141f. The points of attachments of the tubing 134f to the tube 138f is between the inlet 139f and outlet 140f and is demonstrated in the figure as 142f. The multiple rings 143f of the coil are demonstrated in the figure as dotted lines. The chamber may be partially collapsed by pulling some of the rings of the coil together or fully collapsed by pulling all of the rings of the coil together as has been demonstrated in this figure. The distance 144f and 145f between the two

adjacent rings of the coil 143f, the ridges 146f or the grooves 147f may or may not be equal when partially collapsed. When fully collapsed, the inlet end 136f of the tube 135f may fuse or mate with the outlet end 140f of the outlet tube 138f as has been demonstrated in this figure.

Fig 5A is an expanded cross-sectional view of the inlet end 2a of the invention as described in Fig 1A. Figure5A is an expanded cross –sectional view of the inlet end 2a of the MDI chamber 1a as described in figure 1A.

The inlet end has been illustrated in this figure as 148a (corresponds to 2a of figure 1A) with an outer circumference 149a. It has three hollow cylindrical inlet tubes, a central tube 150a (corresponds to 7a of figure 1A) and two peripheral tubes 151a (corresponds to 10a of figure 1A) and 152a (corresponds to13a of figure 1A) located at three o'clock to nine o'clock positions, respectively.

Fig 5B is an expanded cross-sectional view according to the first alternative embodiment of the present invention of the inlet end 2a as described in Fig 5A. . The inlet end has been illustrated in this figure as 148b (corresponds to 2a of figure 1A) with an outer circumference 149b. It has three hollow cylindrical inlet tubes, a central tube 150b (corresponds to 7a of figure 1A) and two peripheral tubes 151b (corresponds to 10a of figure 1A) and 152b (corresponds to13a of figure 1A) located at three o'clock to nine o'clock positions. The inlet of the peripheral tube 151b splits into multiple micrometric openings 153b at it's outlet distributed along one hemisphere of the inlet end 148b. The inlet of the peripheral tube 152b similarly splits into multiple micrometric openings 154b at it's outlet distributed along the other hemisphere of the inlet end 148b of the MDI chamber. The aerosol particles from the nebulizer chamber enter into the MDI chamber either through the central inlet tube 150b or through the inlet ends 151b and 152b of the peripheral tubes. After

entering the inlet ends 151b and 152b of the peripheral tubes, the aerosol particles enter into the MDI chamber through the multiple micrometric openings 153b and 154b. Hence the aerosol particles and or gas(es)move from the nebulizer chamber to the MDI chamber through central and or peripheral connections.

Fig 6A is an expanded cross-sectional view of the inhalation/exhalation valve assemblies 32a or 35a of the invention as described in Fig 1A .In figure 1A the outlet tube of the MDI 16a has been demonstrated to have two valve assemblies disposed between the inlet end 17a and the outlet end 18a –the inhalation valve assembly and an exhalation valve assembly. The two valve assemblies are illustrated here in figure 6A. The inhalation/exhalation flap valve assembly has a circular flap valve seat 155a shown as the shaded area in this figure that has a circular opening 158a. The flap valve seat has an outer circumference 156a and an inner circumference 157a. A circular flap valve 159a is attached to the flap valve seat 155a at point 160a as demonstrated by a dark curvilinear line. The rest of the flap valve has a free edge161a as demonstrated by the dotted line that rests on the flap valve seat 155a. On inhalation, the free edge of the inhalation flap valve moves away from the valve seat for the aerosol particles to move from the MDI chamber to the patient through the opening in the valve seat. On exhalation, the free edge of the flap valve moves towards the flap valve seat and closes the opening to prevent any flow of gas exhaled by the patient from entering into the MDI chamber thus avoiding re-breathing of carbon dioxide on the next inhalation. The exhalation flap valve assembly has a flap valve, the free edge of which presses against the flap valve seat on inhalation and completely occludes the opening to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the mouthpiece or MDI chamber on inhalation. On exhalation the free edge of the flap valve

moves away from the flap valve seat for the air exhaled by the patient to escape into the atmosphere from the opening in the MDI outlet tube/mouthpiece /facemask.

Fig 6B is an expanded cross-sectional view of the first alternative embodiment of the present invention of the inhalation/exhalation valve assemblies 32a or 35a as described in Fig 6A. In figure 1A the outlet tube of the MDI 16a has been demonstrated to have two valve assemblies disposed between the inlet end 17a and the outlet end 18a –the inhalation valve assembly and an exhalation valve assembly .The expanded views of the two valve assemblies are illustrated here in figure 6B.The inhalation /exhalation flap valve assembly has a circular flap valve seat 155b shown as the shaded area in this figure that has a circular opening 158b. The flap valve seat has an outer circumference 156b and an inner circumference 157b. A circular flap valve 159b is attached to the flap valve seat 155b at point 160b as demonstrated by a dark curvilinear line. The major difference between figure 6A and 6B is that the attachment of the flap valve to the valve seat in figure 6B on the superior aspect of the valve seat as opposed to the lateral aspect as shown in figure **6A**. The rest of the flap valve has a free edge161b as demonstrated by the dotted line that rests on the flap valve seat 155b. On inhalation, the free edge of the inhalation flap valve moves away from the valve seat for the aerosol particles to move from the MDI chamber to the patient through the opening in the valve seat. On exhalation, the free edge of the flap valve moves towards the flap valve seat and closes the opening to prevent any flow of gas exhaled by the patient from entering into the MDI chamber thus avoiding re-breathing of carbon dioxide on the next inhalation. The exhalation flap valve assembly has a flap valve, the free edge of which presses against the flap valve seat on inhalation and completely occludes the opening to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the mouthpiece or MDI chamber on inhalation. On exhalation the free edge of the flap valve moves away from the

flap valve seat for the air exhaled by the patient to escape into the atmosphere from the opening in the MDI outlet tube/ mouthpiece /facemask.

Fig 6C is an expanded cross-sectional view of the second alternative embodiment of the present invention of the inhalation/exhalation valve assemblies 32a or 35a as described in Fig 6A. Figure 6C is an expanded cross–sectional view of an alternative embodiment of the inhalation or exhalation flap valve assemblies as shown in figures 6A and 6B. The expanded views of the two valve assemblies are illustrated here in figure 6C. The inhalation /exhalation flap valve assembly has a circular flap valve seat 155c shown as the shaded area in this figure that has a circular opening 158c. The flap valve seat has an outer circumference 156c and an inner circumference 157c. The circular flap valve 159c is now split into two hemispheres 160c and 161c. The flap valve 160c is attached to the flap valve seat 155c at point 162c as demonstrated by a dark curvilinear line. The rest of the flap valve has a free edge163c as demonstrated by the dotted line that rests on the flap valve seat 155c. The flap valve 161c is attached to the flap valve seat 155c at point 164c as demonstrated by a dark curvilinear line. The rest of the flap valve has a free edge165c as demonstrated by the dotted line that rests on the flap valve seat 155c. The two free edges meet at the center line 166c such that there is no gap between the two free edges. On inhalation, the two free edges of the inhalation flap valve move away from the valve seat for the aerosol particles to move from the MDI chamber to the patient through the opening in the valve seat. On exhalation, the free edges of the flap valve move towards the flap valve seat and close the opening to prevent any flow of gas exhaled by the patient from entering into the MDI chamber thus avoiding re-breathing of carbon dioxide on the next inhalation. In the exhalation flap valve assembly, the two free edges of the flap valve presses against the flap valve seat on inhalation and completely occlude the opening to prevent any room air entrainment i.e. not allowing the air from the

atmosphere to enter into the mouthpiece or MDI chamber on inhalation. On exhalation the free edges of the flap valve move away from the flap valve seat for the air exhaled by the patient to escape into the atmosphere from the opening in the MDI outlet tube/mouthpiece /facemask.

Fig 7A is a plan view of the longitudinal length of the mouthpiece according to one embodiment of the present invention. . The mouthpiece is a hollow cylindrical tube that is connected to the MDI chamber at one end and to the patient at the other end for inhalation of the aerosol medication generated either by the nebulizer or by the MDI in the device demonstrated in figure1A. In figure 1A the outlet tube of the MDI 16a has been demonstrated to have two valve assemblies disposed between the inlet end 17a and the outlet end 18a –the inhalation valve assembly and an exhalation valve assembly. The mouthpiece that is illustrated in this figure as 166a is attached to the outlet end 18a of the tube 16a shown in figure1A. The mouthpiece 166a has an inlet end 167a and an outlet end 168a. Instead of the flap valve assemblies being located in the outlet tube 16a of figure 1A, the inhalation valve assembly and an exhalation valve assembly could alternatively be disposed between the inlet end 167a and the outlet end 168a of the mouthpiece 166a. The inhalation flap valve assembly has a circular flap valve seat 169a that has a circular opening 170a and a flap valve 171a as demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 172a that has a circular opening 173a and a flap valve 174a as demonstrated by the dotted line. On inhalation, the inhalation flap valve171a moves away from the valve seat 169a for the aerosol particles to move from the MDI chamber to the patient through the opening 170a in the valve seat 169a of the mouthpiece 166a. On exhalation, the flap valve 171a moves towards the flap valve seat 169a and closes the opening 170a to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 1a thus avoiding re-breathing of

carbon dioxide on the next inhalation. The flap valve seat 169a prevents any protrusion of the flap valve 171a through the opening 170. The exhalation flap valve assembly has a flap valve 174a that presses against the flap valve seat 172a on inhalation and completely occludes the opening 173a to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the mouthpiece 166a on inhalation. On exhalation the flap valve 174a moves away from the flap valve seat 172a for the air exhaled by the patient to escape into the atmosphere from tube 166a through the opening 173a.

Fig 7B is a plan view of the longitudinal length of the facemask according to one embodiment of the present invention. The facemask is connected to the MDI chamber at one end and to the patient at the other end for inhalation of the aerosol medication generated either by the nebulizer or by the MDI as demonstrated in the device in figure1A. In figure 1A the outlet tube of the MDI 16a has been demonstrated to have two valve assemblies disposed between the inlet end 17a and the outlet end 18a –the inhalation valve assembly and an exhalation valve assembly. The facemask that is illustrated in this figure 7B as 166b is attached to the outlet end 18a of the tube 16a shown in figure1A. The facemask 166b has an inlet end 167b and an outlet end 168b. Instead of the flap valve assemblies being located in the outlet tube 16a of figure 1A, the inhalation valve assembly and an exhalation valve assembly could alternatively be disposed between the inlet end 167b and the outlet end 168b of the facemask 166b. The inhalation flap valve assembly has a circular flap valve seat 169b that has a circular opening 170b and a flap valve 171b as demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 172b that has a circular opening 173b and a flap valve 174b as demonstrated by the dotted line. On inhalation, the inhalation flap valve171b moves away from the valve seat 169b for the aerosol particles to move from the MDI chamber to the patient through the opening 170b in the valve seat 169b of the

mouthpiece 166b. On exhalation, the flap valve 171b moves towards the flap valve seat 169b and closes the opening 170b to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 1a thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 169b prevents any protrusion of the flap valve 171b through the opening 170b. The exhalation flap valve assembly has a flap valve 174b that presses against the flap valve seat 172b on inhalation and completely occludes the opening 173b to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the mouthpiece 166b on inhalation. On exhalation the flap valve 174b moves away from the flap valve seat 172b for the air exhaled by the patient to escape into the atmosphere from tube 166b through the opening 173b. Figure 7B demonstrates an additional inhalation flap valve assembly disposed between the inlet end and the outlet end of the facemask located diametrically opposite to the one described before (166b, 167b, 168b). The additional inhalation valve assembly is optional. It has a circular flap valve seat 175b that has a circular opening 176b and a flap valve 177b as demonstrated by the dotted line. On inhalation, the inhalation flap valve177b moves away from the valve seat 175b for the aerosol particles to move from the MDI chamber to the patient through the opening 176b in the valve seat 175b of the mouthpiece 166b. On exhalation, the flap valve 177b moves towards the flap valve seat 175b and closes the opening 176b to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 1b thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 175b prevents any protrusion of the flap valve 177b through the opening 176b.

Fig 8A is an expanded plan view of the longitudinal length of aerosol delivery apparatus IV according to an alternative embodiment of the present invention as described in Fig 1E. Figure 8A is an expanded plan view of an alternative embodiment of the invention

that may be used with both a metered dose inhaler (MDI) or a nebulizer. The device is similar to the description of the invention in figure 1E with a modification. A universal actuator is disposed between the inlet end and the outlet end of the tube located at the inlet end of the nebulizer chamber. The nozzle of any commercially available MDI canister can be attached to the universal actuator and medication delivered by actuation of the MDI. The inlet end of the tube located at the inlet end of the nebulizer chamber can be attached to one or more gas sources to yield a mixture of gas(es) with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

The MDI chamber 178a has an outlet end 180a. The nebulizer chamber 181a has an inlet end 182a. The inlet end of the MDI chamber and the outlet end of the nebulizer chamber are fused together, the fused ends are labeled as 1792a183a. The outlet end 180a of the MDI chamber 178a has a hollow cylindrical tube 193a with an inlet end 194a and an outlet end 195a. The MDI chamber 178a may be made of plastic, paper, or metal. The chamber 178a may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 196a and grooves 197a.The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 198a of the coil are demonstrated in the figure as dotted lines. The distance 199a and 200a between the two adjacent ridges, rings of the coil, or grooves may be equal. The outlet tube 193a of the MDI chamber 178a has two valve assemblies disposed between the inlet end 194a and the outlet end 195a –the inhalation valve assembly and an exhalation valve assembly. The inhalation flap valve assembly has a circular flap valve seat 209a that has a circular opening 210a and a

flap valve 211a as demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 212a that has a circular opening 213a and a flap valve 214a as demonstrated by the dotted line. On inhalation, the inhalation flap valve 211a moves away from the valve seat 209a for the aerosol particles to move from the MDI chamber 178a to the patient through the opening 210a in the valve seat 209a of the tube 193a. On exhalation, the flap valve 211a moves towards the flap valve seat 209a and closes the opening 210a to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 178a thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 209a prevents any protrusion of the flap valve 211a through the opening 210a. The exhalation flap valve assembly has a flap valve 214a that presses against the flap valve seat 212a on inhalation and completely occludes the opening 213a to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the tube 193a on inhalation. On exhalation the flap valve 214a moves away from the flap valve seat 212a for the air exhaled by the patient to escape into the atmosphere from tube 193a through the opening 213a.
The nebulizer chamber 181a has a hollow cylindrical inlet tube 215a with an inlet end 216a and an outlet end 217a. The inlet and 216a can be attached to a single or multiple gas sources to obtain a mixture of gases with a desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles and /or to deliver a fixed concentration of oxygen to a hypoxemic patient. Alternatively, a universal actuator 207a may be disposed between the inlet end 216e and the outlet end 217a of the tube 215a. The nozzle 206a of a canister 205a of any commercially available MDI may be attached to an actuator 207a. The actuator 207a has an opening or an aperture 208a. On actuation of the MDI canister 205a, the medication aerosol particles are generated through the opening 208a of the actuator 207a.

The nebulizer chamber has an inlet port 229a for connection with a standard small volume nebulizer 230a. The aerosol medication generated with the nebulizer 230a can enter the MDI chamber via a central connection between the MDI chamber and the nebulizer chamber 179a183a. Chamber 181a also has another inlet 231a for connection a reservoir bag 232a. The reservoir bag 232a serves to store the aerosol particles generated by the nebulizer 230a during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The bag 232a has two small inlets 233a and 234a to be connected to one or more gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

Fig 8B is an expanded plan view of the longitudinal length of aerosol delivery apparatus IV according to the first alternative embodiment of the present invention as described in Fig 8A. Figure 8B is an expanded plan view of an alternative embodiment of the invention that may be used with both a metered dose inhaler (MDI) or a nebulizer. The device is similar to the description of the invention in figure 8A with modifications. At the inlet end of the nebulizer chamber, there are two hollow concentric tubes, an inner and an outer. A universal actuator is disposed between the inlet end and the outlet end of the inner concentric tube. The inlet end of the inner concentric hollow tube is closed and the outlet end is open and in communication with the nebulizer chamber. The nozzle of any commercially available MDI canister can be attached to the universal actuator and medication delivered by actuation of the MDI into the nebulizer chamber through outlet end of the tube that is in communication with the nebulizer chamber. The outlet concentric tube is fused with the inlet end of the nebulizer chamber at one end and is open at the opposite end. Hence the gas(es)

from the atmosphere or another outside gas source can flow into the nebulizer chamber from the inlet open inlet end of the outer concentric tube through the connection between the outlet end of the outer concentric tube and the inlet end of the nebulizer chamber. The flow is only peripheral and there is no central flow as the inlet end of the inner concentric tube is closed. The open end of the outer concentric tube can be attached to one or more gas sources to yield a mixture of gas(es) with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

The MDI chamber 178b has an outlet end 180b. The nebulizer chamber 181b has an inlet end 182b which may be a single opening or it may have multiple micrometric openings. The inlet end of the MDI chamber and the outlet end of the nebulizer chamber are fused together, the fused ends are labeled as 179b183b. The outlet end 180b of the MDI chamber 178b has a hollow cylindrical tube 193b with an inlet end 194b and an outlet end 195b. The MDI chamber 178b may be made of plastic, paper, or metal. The chamber 178b may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 196b and grooves 197b. The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 198b of the coil are demonstrated in the figure as dotted lines. The distance 199b and 200b between the two adjacent ridges, rings of the coil, or grooves may be equal. The outlet tube 193b of the MDI chamber 178b has two valve assemblies disposed between the inlet end 194b and the outlet end 195b –the inhalation valve assembly and an exhalation valve assembly. The inhalation flap valve assembly has a circular flap valve seat 209b that has a circular opening 210b and a flap valve 211b as

demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 212b that has a circular opening 213b and a flap valve 214b as demonstrated by the dotted line. On inhalation, the inhalation flap valve 211b moves away from the valve seat 209b for the aerosol particles to move from the MDI chamber 178b to the patient through the opening 210b in the valve seat 209b of the tube 193b. On exhalation, the flap valve 211b moves towards the flap valve seat 209b and closes the opening 210b to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 178b thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 209b prevents any protrusion of the flap valve 211b through the opening 210b. The exhalation flap valve assembly has a flap valve 214b that presses against the flap valve seat 212b on inhalation and completely occludes the opening 213b to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the tube 193b on inhalation. On exhalation the flap valve 214b moves away from the flap valve seat 212b for the air exhaled by the patient to escape into the atmosphere from tube 193b through the opening 213b.

The nebulizer chamber 181b is connected to two hollow cylindrical concentric tubes-a hollow cylindrical inner inlet tube 215b with an inlet end 216b and an outlet end 217b. The inlet end 216b of the inner concentric hollow tube is closed and the outlet end 217b is open and in communication with the nebulizer chamber 181b. A universal actuator 207b may be disposed between the inlet end 216b and the outlet end 217b of the tube 215b. The nozzle 206b of a canister 205b of any commercially available MDI may be attached to an actuator 207b. The actuator 207b has an opening or an aperture 208b. On actuation of the MDI canister 205a, the medication aerosol particles are generated through the opening 208b of the actuator 207b and the medication delivered into the nebulizer chamber 181b through outlet end 217b of the tube 215b. The outlet concentric tube 235b is fused with the inlet end 182b

of the nebulizer chamber 181b at one end and has an opening 236b at the opposite end. Hence the gas(es) from the atmosphere or another outside gas source can flow into the nebulizer chamber 181b from the inlet opening 236b of the outer concentric tube 235b through the connection between the outer concentric tube and the inlet end 182b of the nebulizer chamber181b. The flow is only peripheral and there is no central flow as the inlet end 216b of the inner concentric tube 215b is closed. The open end 236b of the outer concentric tube 235a can be attached to one or more gas sources to yield a mixture of gas(es) with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.
The nebulizer chamber has an inlet port 229b for connection with a standard small volume nebulizer 230b. The aerosol medication generated with the nebulizer 230b can enter the MDI chamber via a central connection between the MDI chamber and the nebulizer chamber 179e183e. Chamber 181b also has another inlet 231b for connection a reservoir bag 232b. The reservoir bag 232b serves to store the aerosol particles generated by the nebulizer 230b during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The bag 232b has two small inlets 233b and 234b to be connected to one or more gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

Fig 8C is an expanded plan view of the longitudinal length of aerosol delivery apparatus IV according to the second alternative embodiment of the present invention as described in Fig 8A. Figure 8C is an expanded view of an alternative embodiment of the invention that may be used with both a metered dose inhaler (MDI) or a nebulizer. The

device is similar to the description of the invention in figure 8B with a single modification. At the inlet end of the nebulizer chamber, there are two hollow concentric tubes, an inner and an outer. A universal actuator is disposed between the inlet end and the outlet end of the inner concentric tube. The inlet end of the inner concentric hollow tube is open in this figure as opposed to the closed end observed in figure 8B and the outlet end is open and in communication with the nebulizer chamber. The nozzle of any commercially available MDI canister can be attached to the universal actuator and medication delivered by actuation of the MDI into the nebulizer chamber through outlet end of the tube that is in communication with the nebulizer chamber. The outlet concentric tube is fused with the inlet end of the nebulizer chamber at one end and is open at the opposite end. Hence the gas(es) from the atmosphere or another outside gas source can flow into the nebulizer chamber from the inlet open inlet end of the outer concentric tube through the connection between the outlet end of the outer concentric tube and the inlet end of the nebulizer chamber. The flow is only peripheral and there is no central flow as the inlet end of the inner concentric tube is closed. The open end of the outer concentric tube can be attached to one or more gas sources to yield a mixture of gas(es) with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

The MDI chamber 178c has an outlet end 180c. The nebulizer chamber 181c has an inlet end 182c which may be a single opening or it may have multiple micrometric openings. The inlet end of the MDI chamber and the outlet end of the nebulizer chamber are fused together, the fused ends are labeled as 179c183c.The outlet end 180c of the MDI chamber 178c has a hollow cylindrical tube 193c with an inlet end 194c and an outlet end 195c. The MDI chamber 178c may be made of plastic, paper, or metal. The chamber 178c may be a

fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 196c and grooves 197c. The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 198c of the coil are demonstrated in the figure as dotted lines. The distance 199c and 200c between the two adjacent ridges, rings of the coil, or grooves may be equal. The outlet tube 193c of the MDI chamber 178c has two valve assemblies disposed between the inlet end 194c and the outlet end 195c –the inhalation valve assembly and an exhalation valve assembly. The inhalation flap valve assembly has a circular flap valve seat 209c that has a circular opening 210c and a flap valve 211c as demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 212c that has a circular opening 213c and a flap valve 214c as demonstrated by the dotted line. On inhalation, the inhalation flap valve 211c moves away from the valve seat 209c for the aerosol particles to move from the MDI chamber 178c to the patient through the opening 210c in the valve seat 209c of the tube 193c. On exhalation, the flap valve 211c moves towards the flap valve seat 209c and closes the opening 210c to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 178c thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 209c prevents any protrusion of the flap valve 211c through the opening 210c. The exhalation flap valve assembly has a flap valve 214c that presses against the flap valve seat 212c on inhalation and completely occludes the opening 213c to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the tube 193c on inhalation. On exhalation the flap valve 214c moves away from the flap valve seat 212c for the air exhaled by the patient to escape into the atmosphere from tube 193c through the opening 213c.

The nebulizer chamber 181c is connected to two hollow cylindrical concentric tubes-a hollow cylindrical inner inlet tube 215c with an inlet end 216c and an outlet end 217c. The inlet end 216c of the inner concentric hollow tube is open and the outlet end 217c is in communication with the nebulizer chamber 181c. A universal actuator 207c may be disposed between the inlet end 216c and the outlet end 217c of the tube 215c. The nozzle 206c of a canister 205c of any commercially available MDI may be attached to an actuator 207c. The actuator 207c has an opening or an aperture 208c. On actuation of the MDI canister 205c, the medication aerosol particles are generated through the opening 208c of the actuator 207c and the medication delivered into the nebulizer chamber 181c through outlet end 217c of the tube215c. The outlet concentric tube 235c is fused with the inlet end 182c of the nebulizer chamber 181c at one end and has an opening 236c at the opposite end. Hence the gas(es) from the atmosphere or another outside gas source can flow into the nebulizer chamber 181c from the inlet openings 236c of the outer concentric tube 235c and the inlet opening 216c of the inner concentric tube 235c through the connections between the outer concentric tube 235c and the nebulizer chamber181c and the inner concentric tube 215c and the inlet end 182c of the nebulizer chamber181c. The flow is now both central and peripheral from the outside source to the nebulizer chamber. The open end 236c of the outer concentric tube 235c and the open end 216c of the inner tube 215c can be attached to one or more gas sources to yield a mixture of gas(es) with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

The nebulizer chamber has an inlet port 229c for connection with a standard small volume nebulizer 230c. The aerosol medication generated with the nebulizer 230c can enter the MDI chamber via a central connection between the MDI chamber and the nebulizer

chamber 179c183c. Chamber 181c also has another inlet 231c for connection a reservoir bag 232c. The reservoir bag 232c serves to store the aerosol particles generated by the nebulizer 230c during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The bag 232c has two small inlets 233c and 234c to be connected to one or more gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

Fig 8D is an expanded plan view of the longitudinal length of aerosol delivery apparatus IV according to the alternative embodiment of the present invention as described in Fig 2E. Figure 8Dis an expanded view of an alternative embodiment of the invention that may be used with both a metered dose inhaler (MDI) or a nebulizer. The device is similar to the description of the invention in figure 2E with modifications. A universal actuator is disposed between the inlet end and the outlet end of the tube located at the inlet end of the nebulizer chamber. The nozzle of any commercially available MDI canister can be attached to the universal actuator and medication delivered by actuation of the MDI. The inlet end of the tube located at the inlet end of the nebulizer chamber can be attached to one or more gas sources to yield a mixture of gas(es) with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

The MDI chamber 178d has an outlet end 180d. The nebulizer chamber 181d has an inlet end 182d. The inlet end of the MDI chamber 1and the outlet end of the nebulizer chamber are fused together, the fused ends are labeled as 179d183d.The outlet end 180d of the MDI chamber 178d has a hollow cylindrical tube 193d with an inlet end 194d and an

outlet end 195d. The MDI chamber 178d may be made of plastic, paper, or metal. The chamber 178d may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 196d and grooves 197d. The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 198a of the coil are demonstrated in the figure as dotted lines. The distance 199d and 200d between the two adjacent ridges, rings of the coil, or grooves may be equal.

The outlet tube 193d of the MDI chamber 178d has two valve assemblies disposed between the inlet end 194d and the outlet end 195d –the inhalation valve assembly and an exhalation valve assembly. The inhalation flap valve assembly has a circular flap valve seat 209d that has a circular opening 210d and a flap valve 211d as demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 212d that has a circular opening 213d and a flap valve 214d as demonstrated by the dotted line. On inhalation, the inhalation flap valve 211d moves away from the valve seat 209d for the aerosol particles to move from the MDI chamber 178d to the patient through the opening 210d in the valve seat 209d of the tube 193d. On exhalation, the flap valve 211d moves towards the flap valve seat 209d and closes the opening 210d to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 178d thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 209d prevents any protrusion of the flap valve 211d through the opening 210d. The exhalation flap valve assembly has a flap valve 214d that presses against the flap valve seat 212d on inhalation and completely occludes the opening 213d to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the tube 193d on inhalation. On exhalation the flap valve 214d moves away from the flap

valve seat 212d for the air exhaled by the patient to escape into the atmosphere from tube 193d through the opening 213d.

The nebulizer chamber 181d has an hollow cylindrical inlet tube 215d at it's inlet end 182d. The inlet tube 215d has an inlet end 216d and an outlet end 217d. The inlet end 182d of the nebulizer chamber 181d may be closed at it's periphery 246d shown as the shaded area in the figure and open in the center 247d where it fuses with the tube 215d and the two openings 217d and 247d fuse with each other. A universal actuator 207d may be disposed between the inlet end 216d and the outlet end 217d of the tube 215d. The nozzle 206d of a canister 205d of any commercially available MDI may be attached to an actuator 207d. The actuator 207d has an opening or an aperture 208d. On actuation of the MDI canister 205d, the medication aerosol particles are generated through the opening 208d of the actuator 207d. The flow of the gas(es) from the nebulizer chamber 181d to the MDI chamber is central through the opening 216d of the tube 215d as the peripheral part of the MDI chambers inlet 182d is closed.

The nebulizer chamber has an inlet port 229d for connection with a standard small volume nebulizer 230d. The aerosol medication generated with the nebulizer 230d can enter the MDI chamber via a central connection between the MDI chamber and the nebulizer chamber 179e183e. Chamber 181d also has another inlet 231d for connection a reservoir bag 232d. The reservoir bag 232d serves to store the aerosol particles generated by the nebulizer 230d during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The bag 232d has two small inlets 233d and 234d to be connected to one or more gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration

of oxygen to a hypoxemic patient. Alternatively, the reservoir bag 232d may be replaced by a corrugated plastic reservoir tubing 237d that may be connected to inlet end 216d of the nebulizer chamber 181d. The reservoir tubing 237d may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 238d and grooves 239d. The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 240d of the coil are demonstrated in the figure as dotted lines. The distance 241d and 242d between the two adjacent ridges, rings of the coil, or grooves may be equal. The reservoir bag 232d or reservoir tubing 237d serves to store the aerosol particles generated by the nebulizer 230d during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The reservoir tubing has an inlet end 238d that may have a hollow cylindrical inlet tube 243d with an inlet end 244d and an outlet end 245d. The inlet end 244d can be attached to a single or multiple gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the
The MDI 205d can be connected to the inlet end 244d of the inlet tube 243d and on actuation the aerosol particles generated by the MDI will be transferred from the reservoir tubing 232d to the nebulizer chamber 181d and then to the MDI chamber 178d.

Fig 8E is an expanded plan view of the longitudinal length of aerosol delivery apparatus IV according to the first alternative embodiment of the present invention as described in Fig 8D. Figure 8E is an expanded view of an alternative embodiment of the invention that may be used with both a metered dose inhaler (MDI) or a nebulizer. The device is similar to the description of the invention in figure 2E with modifications. A

universal actuator is disposed between the inlet end and the outlet end of the tube located at the inlet end of the nebulizer chamber. The nozzle of any commercially available MDI canister can be attached to the universal actuator and medication delivered by actuation of the MDI. The inlet end of the tube located at the inlet end of the nebulizer chamber can be attached to one or more gas sources to yield a mixture of gas(es) with desired density, oxygen concentration, viscosity,and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

The MDI chamber 178e has an outlet end 180e.The nebulizer chamber 181e has an inlet end 182e .The inlet end of the MDI chamber and the outlet end of the nebulizer chamber are fused together, the fused ends are labeled as 179183e. The outlet end 180e of the MDI chamber 178e has a hollow cylindrical tube 193e with an inlet end 194e and an outlet end 195e. The MDI chamber 178e may be made of plastic, paper, or metal. The chamber 178e may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 196e and grooves 197e.The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 198e of the coil are demonstrated in the figure as dotted lines. The distance 199e and 200e between the two adjacent ridges, rings of the coil, or grooves may be equal.

The outlet tube 193e of the MDI chamber 178e has two valve assemblies disposed between the inlet end 194e and the outlet end 195e –the inhalation valve assembly and an exhalation valve assembly .The inhalation flap valve assembly has a circular flap valve seat 209e that has a circular opening 210e and a flap valve 211e as demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 212e that has a circular

opening 213e and a flap valve 214e as demonstrated by the dotted line. On inhalation, the inhalation flap valve 211e moves away from the valve seat 209e for the aerosol particles to move from the MDI chamber 178e to the patient through the opening 210e in the valve seat 209e of the tube 193e. On exhalation, the flap valve 211e moves towards the flap valve seat 209e and closes the opening 210e to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 178e thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 209e prevents any protrusion of the flap valve 211e through the opening 210e. The exhalation flap valve assembly has a flap valve 214e that presses against the flap valve seat 212e on inhalation and completely occludes the opening 213e to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the tube 193e on inhalation. On exhalation the flap valve 214e moves away from the flap valve seat 212e for the air exhaled by the patient to escape into the atmosphere from tube 193e through the opening 213e.

The nebulizer chamber 181e has an hollow cylindrical inlet tube 215e at it,s inlet end 182e.The inlet tube 215e has an inlet end 216e and an outlet end 217e.The inlet end 182e of the neulizer chamber 181e is open quite unlike the closed periphery 246e shown as the shaded area in figure8D. The inlet end 216e of the inlet tube 215e is closed. A universal actuator 207e may be disposed between the inlet end 216e and the outlet end 217e of the tube 215e. The nozzle 206e of a canister 205e of any commercially available MDI may be attached to an actuator 207e. The actuator 207e has an opening or an aperture 208e. On actuation of the MDI canister 205e, the medication aerosol particles are generated through the opening 208e of the actuator 207e.The flow of the gas(es) from the nebulizer chamber 181e to the MDI chamber is peripheral through the opening 246e of the nebulizer chamber 181e

.There is no central flow of gas(es)from the nebulizer chamber to the MDI chamber as the inlet end 216e of the inlet tube tube 215e is closed.

The nebulizer chamber has an inlet port 229e for connection with a standard small volume nebulizer 230e. The aerosol medication generated with the nebulizer 230e can enter the MDI chamber via a central connection between the MDI chamber and the nebulizer chamber 179e183e. Chamber 181e also has another inlet 231e for connection a reservoir bag 232e. The reservoir bag 232e serves to store the aerosol particles generated by the nebulizer 230e during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The bag 232e has two small inlets 233e and 234e to be connected to one or more gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

Alternatively, the reservoir bag 232e may be replaced by a corrugated plastic reservoir tubing 237e that may be connected to inlet end 216e of the nebulizer chamber 181e. The reservoir tubing 237e may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 238e and grooves 239e.The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 240e of the coil are demonstrated in the figure as dotted lines. The distance 241e and 242e between the two adjacent ridges, rings of the coil, or grooves may be equal .The reservoir bag 232e or reservoir tubing 237e serves to store the aerosol particles generated by the nebulizer 230e during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery.

The reservoir bag may be made of plastic, neoprene, paper, or metal. The reservoir tubing has an inlet end 238e that may have a hollow cylindrical inlet tube 243e with an inlet end 244e and an outlet end 245e.The inlet end 244e can be attached to a single or multiple gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve theThe MDI 205e can be connected to the inlet end 244e of the inlet tube 243e and on actuation the aerosol particles generated by the MDI will be transferred from the reservoir tubing 232e to the nebulizer chamber 181e and then to the MDI chamber 178e

Fig 8F is an expanded plan view of the longitudinal length of aerosol delivery apparatus IV according to the second alternative embodiment of the present invention as described in Fig 8D. Figure 8F is an expanded view of an alternative embodiment of the invention that may be used with both a metered dose inhaler (MDI) or a nebulizer. The device is similar to the description of the invention in figure 2E with modifications. A universal actuator is disposed between the inlet end and the outlet end of the tube located at the inlet end of the nebulizer chamber. The nozzle of any commercially available MDI canister can be attached to the universal actuator and medication delivered by actuation of the MDI. The inlet end of the tube located at the inlet end of the nebulizer chamber can be attached to one or more gas sources to yield a mixture of gas(es) with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

The MDI chamber 178f has an outlet end 180f.The nebulizer chamber 181f has an inlet end 182f.The inlet end of the MDI chamber and the outlet end of the nebulizer chamber are fused together, the fused ends are labeled as 179f183f. The outlet end 180f of the MDI chamber 178f has a hollow cylindrical tube 193f with an inlet end 194f and an outlet end 195f. The MDI chamber 178f may be made of plastic, paper, or metal. The chamber 178f

may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 196f and grooves 197f.The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 198f of the coil are demonstrated in the figure as dotted lines. The distance 199f and 200f between the two adjacent ridges, rings of the coil, or grooves may be equal

The outlet tube 193f of the MDI chamber 178f has two valve assemblies disposed between the inlet end 194f and the outlet end 195f –the inhalation valve assembly and an exhalation valve assembly .The inhalation flap valve assembly has a circular flap valve seat 209f that has a circular opening 210f and a flap valve 211f as demonstrated by the dotted line. The exhalation valve assembly has a circular flap valve seat 212f that has a circular opening 213f and a flap valve 214f as demonstrated by the dotted line. On inhalation, the inhalation flap valve 211f moves away from the valve seat 209f for the aerosol particles to move from the MDI chamber 178f to the patient through the opening 210f in the valve seat 209f of the tube 193f. On exhalation, the flap valve 211f moves towards the flap valve seat 209f and closes the opening 210f to prevent any flow of gas exhaled by the patient from entering into the MDI chamber 178f thus avoiding re-breathing of carbon dioxide on the next inhalation. The flap valve seat 209f prevents any protrusion of the flap valve 211f through the opening 210f. The exhalation flap valve assembly has a flap valve 214f that presses against the flap valve seat 212f on inhalation and completely occludes the opening 213f to prevent any room air entrainment i.e. not allowing the air from the atmosphere to enter into the tube 193f on inhalation. On exhalation the flap valve 214f moves away from the flap valve seat 212f for

the air exhaled by the patient to escape into the atmosphere from tube 193f through the opening 213f.

The nebulizer chamber 181f has an hollow cylindrical inlet tube 215f at it,s inlet end 182f.The inlet tube 215f has an inlet end 216f and an outlet end 217f.The inlet end 182f of the neulizer chamber 181f is open quite like the opening in figure 8E. The inlet end 216f of the inlet tube 215f is also open unlike the closed inlet end in figure 8E. A universal actuator 207f may be disposed between the inlet end 216f and the outlet end 217f of the tube 215f. The nozzle 206f of a canister 205f of any commercially available MDI may be attached to an actuator 207f. The actuator 207f has an opening or an aperture 208f. On actuation of the MDI canister 205f, the medication aerosol particles are generated through the opening 208f of the actuator 207f.The flow of the gas(es) from the nebulizer chamber 181f to the MDI chamber is peripheral through the opening 246f of the nebulizer chamber 181f .There is central and peripheral flow of gas(es)from the nebulizer chamber to the MDI chamber through the inlet end 216f of the inlet tube tube 215f and the inlet opening 182f of the nebulizer chamber 181f, respectively.

The nebulizer chamber has an inlet port 229f for connection with a standard small volume nebulizer 230f. The aerosol medication generated with the nebulizer 230f can enter the MDI chamber via a central connection between the MDI chamber and the nebulizer chamber 179f183f. Chamber 181f also has another inlet 231f for connection a reservoir bag 232f. The reservoir bag 232f serves to store the aerosol particles generated by the nebulizer 230f during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The bag 232f has two small inlets 233f and 234f to be connected to one or more gas sources

to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve the delivery of aerosol particles as well as deliver a fixed concentration of oxygen to a hypoxemic patient.

Alternatively, the reservoir bag 232f may be replaced by a corrugated plastic reservoir tubing 237f that may be connected to inlet end 216f of the nebulizer chamber 181f. The reservoir tubing 237f may be a fixed volume chamber or a collapsible/expandable chamber. The chamber may be cylindrical with smooth edges or cylindrical with multiple ridges 238f and grooves 239f.The chamber may be made of stiff corrugated plastic that may not require any additional support to maintain patency of the chamber. Alternatively the chamber may be supported with a metal or plastic coil with multiple rings. The multiple rings 240f of the coil are demonstrated in the figure as dotted lines. The distance 241f and 242f between the two adjacent ridges, rings of the coil, or grooves may be equal .The reservoir bag 232f or reservoir tubing 237f serves to store the aerosol particles generated by the nebulizer 230f during the exhalation phase to be inhaled on the next breath thus improving aerosol medication delivery. The reservoir bag may be made of plastic, neoprene, paper, or metal. The reservoir tubing has an inlet end 238f that may have a hollow cylindrical inlet tube 243f with an inlet end 244f and an outlet end 245f.The inlet end 244f can be attached to a single or multiple gas sources to obtain a mixture of gases with desired density, oxygen concentration, viscosity, and humidity to improve theThe MDI 205f can be connected to the inlet end 244f of the inlet tube 243f and on actuation the aerosol particles generated by the MDI will be transferred from the reservoir tubing 232f to the nebulizer chamber 181f and then to the MDI chamber 178f.

It is noted that the illustration (drawings) and description of the preferred embodiments have been provided merely for the purpose of explanation and although the invention has been described herein with reference to particular means, materials and embodiments, the invention is not intended to be limited to the particulars disclosed herein; rather the invention intents to all functionally equivalent structures, methods and uses such as are within the scope of the appended claims.